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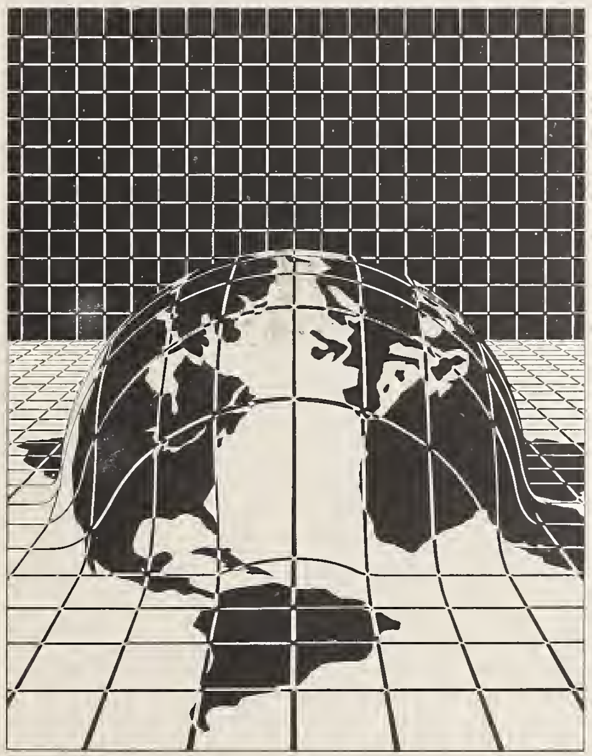
PROCEEDINGS FROM THE

GEOGRAPHIC INFORMATION SYSTEMS AWARENESS SEMINAR

Salt Lake City, Utah
May 16-19, 1988



Intermountain
Region

January 1989

PROCEEDINGS--

GEOGRAPHIC INFORMATION SYSTEMS AWARENESS SEMINAR

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FOREWORD

A Geographic Information System (GIS) is a computer-based toolkit used to analyze various data sets which have unique geographically locatable characteristics. The analysis results can be displayed in tabular format such as reports or spreadsheets and in graphical format such as printed maps. Also included in GIS is a powerful database management system which facilitates the storage, updating and retrieval of attribute information related to these geographic features. Because of these capabilities, the use of Geographic Information Systems will play a key role in the future of natural resource management.

* * *

The Geographic Information Systems Awareness Seminar, sponsored by the Intermountain Region of the Forest Service, hosted speakers from the Intermountain, Northern, Pacific Northwest, and Eastern Regions, Research, the Washington Office, and private industry. This seminar represents the first time a major effort has been directed specifically to increase awareness of Geographic Information Systems.

The following Intermountain Region individuals contributed significantly to the development and presentation of the seminar:

Steering Committee	**John Butt**, Planning & Budget **David Graham**, State & Private Forestry **Jack Griswold**, Challis National Forest **Jim Haskell**, Information Systems **John Lupis**, Engineering **Don Nebeker**, Uinta National Forest **George Roether**, Timber Management
Technical Working Group	**Wayne Beddes**, Engineering **Roberta Beverly**, Planning & Budget **Hank Cheatham**, Timber Management **Mike Lunt**, Engineering **Dave Prevedel**, Information Systems **Dave Winn**, Wildlife & Fisheries
Seminar Chair	**Roberta Beverly**, Planning & Budget

Approximately 150 participants from private industry, colleges and universities, and Federal and State organizations attended.

It is hoped that the information contained within these proceedings will enlighten all of us to a better awareness of Geographic Information Systems.

J. S. TIXIER
Regional Forester
Intermountain Region

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Session 2--*Objective: To become aware of Geographic Information Systems and typical Forest applications*

SESSION 1

OBJECTIVE: To become aware of the general capabilities and application of Geographic Information Systems.

Chaired by:

James Haskell, Director, Information Systems, Intermountain Region,
Forest Service, Ogden, Utah

Dave Graham, Director, State and Private Forestry, Intermountain Region,
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GEOGRAPHIC INFORMATION SYSTEM -- WHAT IS IT?

Michael Lunt

ABSTRACT

A Geographic Information System (GIS) is designed to accept large volumes of spatial data, derived from a variety of sources, including remote sensors, and to store, retrieve, manipulate, analyze, and display these data according to user-defined specifications. This paper describes what data is typically required as input in a Forest Service GIS, data standards, and what to plan for in the near future as we prepare to take advantage of the power of Geographic Information Systems.

THE DECISION-MAKING PROCESS: MANUAL VS. AUTOMATED

The Manual Approach

In making decisions about our natural resources, we rely on a wide variety of data sources in which data exist in diverse formats. Sorting and organizing sets of diverse source materials can be extremely cumbersome and difficult for the human mind. Typically, the decision-maker converts data to graphical forms, such as overlays, that register to the 1:24,000 map base to delineate timber, range, soil, and other information. This map base serves as a common control network, with all other data normally registered to that 1:24,000-scale map base.

This map base also serves as a source of information. It usually contains basic information about the location of such features as the Forest transportation system, hydrology, land ownership, and elevation. In addition, we use many reports and statistical data to collaborate our decision making.

Paper presented at the Geographic Information Systems Awareness Seminar, Salt Lake City, UT, May 16-19, 1988.

Michael Lunt is the Geometronics Group Leader, Regional Office Engineering, Forest Service, U.S. Department of Agriculture, Ogden, UT.

Some data is handled with more highly technical methods. For example, we often have computer databases or special software to manipulate the data received from our field investigations. We also have access to Global Positioning Systems (GPS) and digital satellite data.

To date, the manual process for assimilating, manipulating, and querying this diverse data simultaneously has been very fragmented and labor intensive.

The Automated Approach

The idea of the GIS is to put all data into digital form (described by coordinates) or tabular form in a central location (a computer). The computer system can draw comparisons against predesigned or spontaneous models established by the user and calculations.

Assuming that the data input source is reliable, this analytical approach provides the user a quick and accurate display of alternatives for specific issues or problems. It allows the user to play "what if" games with the data, while avoiding the laborious process of physically overlaying or otherwise comparing data sets by manual methods.

Finally, automated plotters can display or print various plotted solutions or alternatives. The automated approach provides many advantages over the manual approach:

- It is more versatile.
- The "what if" games can be examined more quickly.
- Files can be updated more easily.
- Large volumes of data can be examined more easily.
- Data displays are more professional and quicker.

The automated approach is, however, very complex. No matter how user-friendly the system may appear to be, the novice can quickly encounter major problems in attempting to overly data. Difficulties may arise through:

- Mixing different source scales.

- Failing to understand cartographic practices as the system mathematically deals with curvature of the earth.

- Making translations between various coordinate systems.

- The calculations of map projections.

- Electronic edge-matching of cartographic data between sheets.

- Misunderstanding the effects of elevation data relative to horizontal position of features.

- Dealing with the measurement of horizontal distances as compared to slope distances.

Through automation, the user can assimilate and manipulate large volumes of data in order to find better solutions for managing the National Forest System resources. The user queries the system, and the computer performs the "number crunching" and displays the results graphically or by producing a report. The GIS is a tool for analyzing and displaying data for the decision maker to evalate. The results are better decisions relative to the management of the National Forests.

SOURCES OF DATA FOR INPUT INTO GIS

Data sources for input into GIS include planimetric files, engineering survey notes, the Global Positioning System (GPS), remote sensing, resource information (see RIP Report), and statistical and tabular data from reports and documents.

Digitizing

Because data type and their sources vary extensively, certain standardization practices are necessary to enable computerized comparisons. This wide variety of data must be converted into a form understood by the computer. Therefore, most sets of data will have to be converted to digitized points, lines, and polygons described by common coordinate systems.

Planimetric Files -- Control Standards for Data Sets

All digital data must be oriented to a specific coordinate system and compared against a standard. The standard agreed upon in our Region is the Forest Service Primary Quad Base Sheets produced at a scale of 1:24,000.

This series of maps has several advantages:

- It is the most detailed map product produced by the Forest Service that covers the entire National Forest areas of interest.

- It is revised on a cycle of from five to seven years.

- These maps meet the National Map Accuracy Standards (NMAS).

- We have a program to completely digitize all planimetric data from these quads within the next six years.

- These quads are the basis for the production of several other Forest Service maps, such as Forest Visitor Maps, Secondary base maps, and travel plans.

Since we have a common control source (1:24,000) for all of the data sets, we can maintain a compatibility between the various map sets. The digital planimetric data from the 1:24,000-scale base maps will serve as the control for other digital data. All other digital data will be registered to this base.

Digital Planimetric data is usually referred to by one of the following:

- Line data
- Planimetric data
- Digital Line Graph (DLG)
- Line Data Files (LDF)
- Cartographic Feature Files (CFF).

DLG data is the term used by the U. S. Geological Survey (USGS) and implies specific standards and formats.

Engineering Survey Notes

Another type of data for input into the GIS can be engineering survey notes (bearings and distances or coordinates), if the survey is tied into a non-local coordinate system such as State Plane or UTM. Most GIS systems can read this kind of data and translate it into graphic or pictorial displays merged properly into the systems coordinate network.

Global Positioning System

The newest technology for collecting coordinates of points (boundary corners, for example) or a series of coordinates along a line (roads, trails, and boundary lines) is the Global Positioning System (GPS). The user places a GPS receiver on a point where they wish to compute a coordinate. This receiver will identify and lock onto four GPS satellites. The position of the receiver is determined by solving four simultaneous equations obtained from the transmissions from the four satellites. Positions may be obtained with accuracies greater than three inches of the true position.

Several GPS satellites are in orbit, and NASA's future payload assignment list schedules satellites to go into orbit on the following schedule:

- Two in June 1989
- Two in September 1989
- One in May 1990
- One in July 1990
- One in October 1990
- Two in February 1991
- One in April 1991

GPS can conceivably be used for inputting coordinate data for monuments, ties to springs, rights-of ways, boundary lines, timber sale boundaries, new roads and trails, and other applications.

Remote Sensing

Information retrievable from aerial photography, radar imagery, thermal infrared, photographic infrared, video and satellite imagery can be digitized and put into the GIS database. Typically this is information about such features as vegetation cover types, soil information, insect and disease damage, etc.

Satellite data and thermal imagery can be obtained in a digital form, rather than a hard copy, and can be evaluated or analyzed by computer-assisted image interpretation techniques. This process usually involves restoring data cells, enhancing features, and interpreting data electronically. Then the process of digitizing and coding must be considered.

Individuals using digital image analysis system will be more productive if they are versed in the electro-optics of sensing, transmission and display technology, numerical analysis, statistics and pattern recognition.

Managing such data is a complex subject best understood by specialists involved in remote sensing activities. It deserves much more serious attention than it is currently receiving relative to the GIS effort.

Resource Data

A special team was formed in the Washington Office with the following objectives:

- Document how the field is currently describing certain land based natural resources.

- Analyze existing coding conventions and make recommendations to develop a uniform approach for certain resource components.

- Develop and test a standard way to organize and display vegetation information as a corporate framework to be used in a GIS.

This team is known as the Resource Information Project (RIP) team. A report of their findings and recommendations can be found in "Resource Information Project: Final Report" dated June 1988.

Large volumes of resource data have been digitized in the Region over the years. Among others, it includes such categories as the following:

- Archeology
- Bedrock
- Coal
- Fuels
- Habitat
- Precipitation
- Streams

- Timber
- Vegetation
- Visuals
- Wildlife

Statistical and Tabular Data

Statistical and tabular data can be extracted from reports and documents and input into the database. For example, planimetric map data includes transportation data (roads and trails) to which we can attach other tabular data such as: road surface type, road maintenance characteristics, and the location of culverts. Statistical and tabular data can conceivably be applicable to recreation sites, water sources, streams, roads, and trails and could also include land ownership data.

DATA STANDARDS

Many hours have been spent developing digitizing techniques and standards for the Base Series Planimetric data files (1:24,000). Line-following devices, optical drum scanners, and photogrammetric instruments have been used for collecting data. Coding conventions and plotting techniques have been developed to produce a versatile product of the highest quality.

As with many high-tech processes, the standards will be improved upon with time. But for now, we have a solid foundation of standards for digitizing planimetric and elevation data. Adherence to the standards will enable us to avoid many problems in the use of the GIS.

One of the most common pitfalls encountered in using a GIS is to assume that we can merge a wide variety of data from varying source scales because we convert the various coordinates to a common coordinate set and common scale.

Converting data from a variety of source scales results in overlapping polygons (that should not overlap) or gaps in data. It is often very difficult to edit the poor relationships between data sets.

The best results are achieved when there are digitizing standards for the base map data (planimetric and elevation data) and resource and other data sets and when there is not a large difference between the scales of data sources.

Recently, Geometronics used two planimetric files of the same geographic area but of different source scales. They plotted both files together at the same map projection and scale. Some of the features were positioned very close between the two sets, while others were displaced almost three miles. The most common deviation was about 1.5 miles.

It is not feasible to **photographically** enlarge a map of 1:10 million scale to 1 inch equals 10 feet and expect to have a map with the accuracy implied by the scale. Similarly, it is not practical to use **digital data** to produce a map much larger in scale than the source.

Figure 1, page 5, gives some idea of the final map scales that should be derived from the various digital source scales.

PROPOSED PLAN FOR DIGITIZING PLANIMETRIC DATA

The source for the Planimetric Data (transportation, hydrology, streams and lakes, landnet, boundaries, etc.), will be the Primary Base Series (1:24,000 scale). There are over 300 elements in the planimetric data that have a unique code for digitizing.

The schedule for digitizing the planimetric data for the Region is outlined in Figure 2, page 5.

PROPOSED PLAN FOR DIGITIZING ELEVATION DATA

Digital elevation data is commonly referred to as DEM data, but this implies specific standards as set forth by the USGS. This data is also referred to as Terrain Data Files (TDF), or simply elevation data.

Figure 3, page 6, outlines the plan for completing digital elevation data for the Region. This data is acquired on a 7.5' quad basis, and several quads are available, in digital form, throughout the Region.

THE FUTURE WITH GIS

The Forest Service has been a leader in the development and use of technology relative to automated mapping and the production of high quality

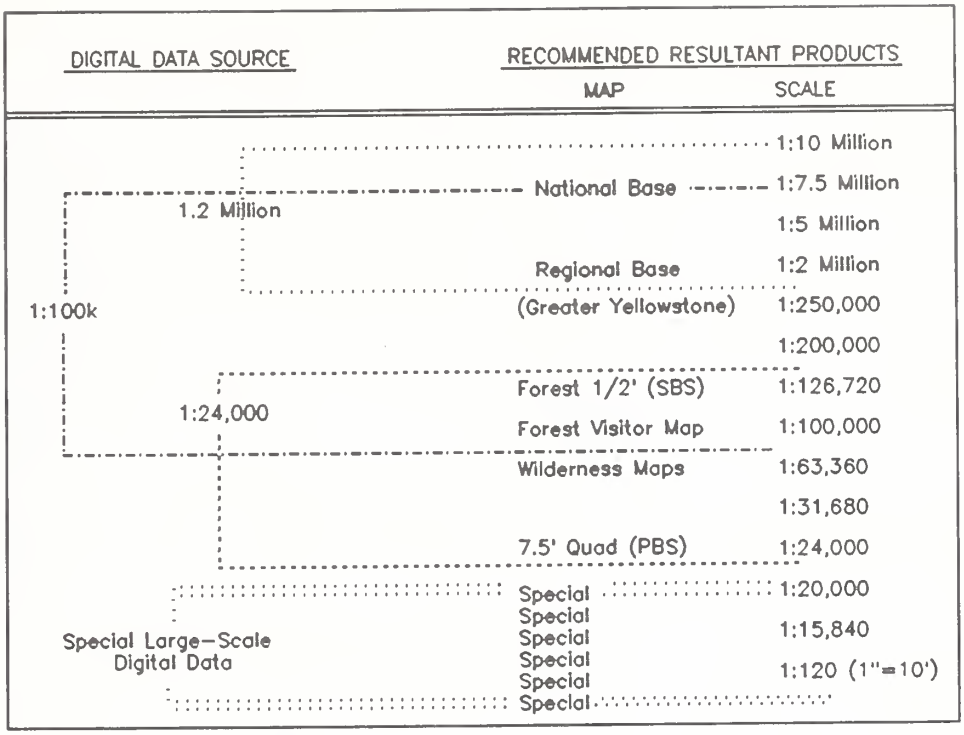

FIGURE 1. Producing maps from digital planimetric data.

FY 1989 Uinta Sawtooth NRA Bridger-Teton Wilderness Areas
FY 1990 Wasatch-Cache Sawtooth South
FY 1991 Fishlake Ashley Targhee Sawtooth North
FY 1992 Caribou incl's Curlew Manti-LaSal Challis Boise
FY 1993 Payette Toiyabe (Carson-Bridgeport)
FY 1994 Toiyabe (Austin-Tonapah) Humboldt

ESTABLISHING THE SCHEDULE

In order to meet the National Map accuracy standards the maps that exist in a 15 minute format must be recompiled. Therefore, those forests with the most 15' quads are pushed to the bottom of the list. Maps older than 5-6 years will not be digitized; therefore, Forests with old maps will be last. Forests that are in the middle of their PBS Revision cycle will stay in the cycle and will be digitized shortly after they are revised in order that the newest maps will be digitized first.

There will be no direct charge to the forests for the digitizing listed to the left.

EXCEPTIONS TO THE SCHEDULE

There may be an opportunity to digitize special projects on a cost reimbursable basis. This will have to be coordinated with the RO Engineering-Geometronics Group.

NOTE: Some planimetric data is available on the following Forests: Bridger-Teton, Boise, Caribou, Dixie, Fishlake, Payette, Salmon, Targhee and Toiyabe

FIGURE 2. Proposed plan for collecting (digitizing) planimetric data

FY 1989 Wasatch-Cache Sawtooth
FY 1990 Fishlake Manti-LaSal Challis Toiyabe (Carson-Bridgeport)
FY 1991 Sawtooth South Toiyabe (Austin-Tonopah)
FY 1992 Humboldt
FY 1993 Caribou-Curlew

Digital elevation data is commonly referred to as DEM data, but this implies specific standards as set forth by the USGS. This data is also referred to as TDF files which stands for Terrain Data Files.

FIGURE 3. Region 4 plan for digitizing elevation data

map products. These maps are symbolized, with high-speed plotters, to accurately portray cartographic features to a National Map Accuracy Standard.

Using laser line-following devices and optical drum scanners associated with automated line-following systems, we have capture and digitized map data as points, lines, and polygons.

As a result of the National GIS Evaluation, the RIP study, and other sources of input, the Forest Service will systematically approach further GIS efforts. (See the National Forest Service GIS Plan.)

Planimetric and elevation data will be digitized as outlined in the previous pages and in accordance with engineering-defined standards. The resource data digitizing most likely will be guided by the RIP Study.

The elements to be digitized are rapidly being defined, and standards are being developed in harmony with this effort. The manpower needs, equipment needs, and cost-analysis plans are being worked on and will evolve as a matter of course.

Many of the pieces to the GIS puzzle are slowly, but methodically, being put into place. The end result will be a well-defined database that adheres to specific standards, which in turn will result in an accurate database of a corporate nature. This system will most likely be very user-friendly and will become a tool in the hands of decision-makers, allowing access to a vast amount of data that is easily manipulated in the process of asking "what if" questions relative to the management of the natural resources.

Evaluating geographic information systems and their capabilities should not be our immediate concern, because other experts are already doing this work. They are looking at many features, including the following:

- terrain modeling
- creating slope and aspect
- drainage networks
- edgematching
- coordinate transformation

- PC compatibility
- smoothing routines
- interactive editing
- sliver removal
- report generation
- zoom/pan capabilities.

At present, the most important thing we can do which will yield the most payoff in the future, is to perform a cost/needs analysis and evaluate the data that we may want to put into the GIS database. We must address questions such as the following:

- Is the data generic in nature?

- How was the data collected (remote sensing, field investigations, etc.)?

- How accurate is the data?

- How old is the data?

- Does it need to be re-inventoried?

- Is it coded in accordance with accepted standards?

We need to become familiar with the National Plan, the RIP Study, and digitizing standards. For those disciplines that may not be represented totally by previous studies, we need to be thinking about the kinds of tabular data we want attached to the graphical data being digitized. For example, we need to ask the following questions:

- What information does Lands want attached to the Land Survey data (section lines, corners, ownership parcels, rights-of-ways, etc.)?

- Does Lands want to create automated status and encumbrance sheets?

- Does Engineering want to attach information to the digitized transportation system, such as road surface type, maintenance characteristics, etc.?

Focusing on cost and needs analysis and data evaluation will enable us to suggest changes to the digitizing standards. We may find, for example, that we need a more detailed breakdown of the transportation system or, perhaps, that we need the boundaries around individual mining claims digitized rather than only the exterior boundary of a mass of overlapping mining claims.

There are many opportunities for each of us to be involved in the GIS effort; several of us will be called upon to participate with special committees to examine different aspects of the GIS process. Our most important challenge now is to build an accurate, strong foundation that will support our GIS needs for the years to come.

THE FOREST SERVICE APPROACH TO IMPLEMENTATION OF GEOGRAPHIC INFORMATION SYSTEM

Henry M. Lachowski

ABSTRACT

In January 1988, the USDA Forest Service initiated a national strategy for implementation of Geographic Information System (GIS) technology. GIS is a tool to assist in management of resource information. The objective of the National strategy is to establish guidelines for management of Forest Service "corporate information" (information that needs to be commonly shared and understood to meet our mission of "Caring for the Land and Serving People"), and to make the GIS technology available for day-to-day resource management activities.

The Forest Service is currently preparing for the adaptation of the new technology. The Controlled Evaluation of GIS, the Resource Information Project and other ongoing projects will contribute to a better definition of what we need and of how we can best use the technology. The Washington Office Information Systems (InS) and Computer Sciences and Telecommunications (CS&T) staffs will coordinate this large effort, along with the National GIS Steering Committee. The "National GIS Plan" outlines the components and actions needed to accomplish this task. The technology procurement is to begin in 1991.

INTRODUCTION

The Forest Service mission requires management of immense amounts of information. The Geographic Information System (GIS) technology is a potential tool to assist in management of spatial, "georeferenced," data that describes the various forest resources.

In January 1988, the Chief of the Forest Service approved a national strategy for implementation of GIS. Information Systems (InS) and Computer Sciences and Telecommunications (CS&T), under the Associate Deputy Chief for Administration, are responsible for guiding the development of this new technology and its adoption into operational use. The "National GIS Plan" (1988) provides guidelines for the Forest Service implementation of GIS.

The following summary of the Forest Service approach to GIS describes GIS and points out what should be considered before getting into this new technology. It also addresses what we are doing now and our implementation plan. Information contained in this paper comes from the various notes, briefing papers, and other materials published by Forest Service, Washington Office Information Systems, and from the author's contacts with various Forest Service units involved in GIS-related work.

WHAT IS GIS?

GIS is an information processing tool to input, store, manipulate, analyze, and display spatial resource data to support the decision-making process of an organization. As shown in Figure 1, next page, it is a combination of computer hardware and software with the primary purpose of managing information. Various types of data are input into a database. Numerous functions and operations can be performed on the various data layers residing in the database. These data layers can represent topography for a given area, boundaries, vegetation types, and many other considerations.

Paper presented at the Geographic Information Systems Awareness Seminar, Salt Lake City, UT, May 16-19, 1988.

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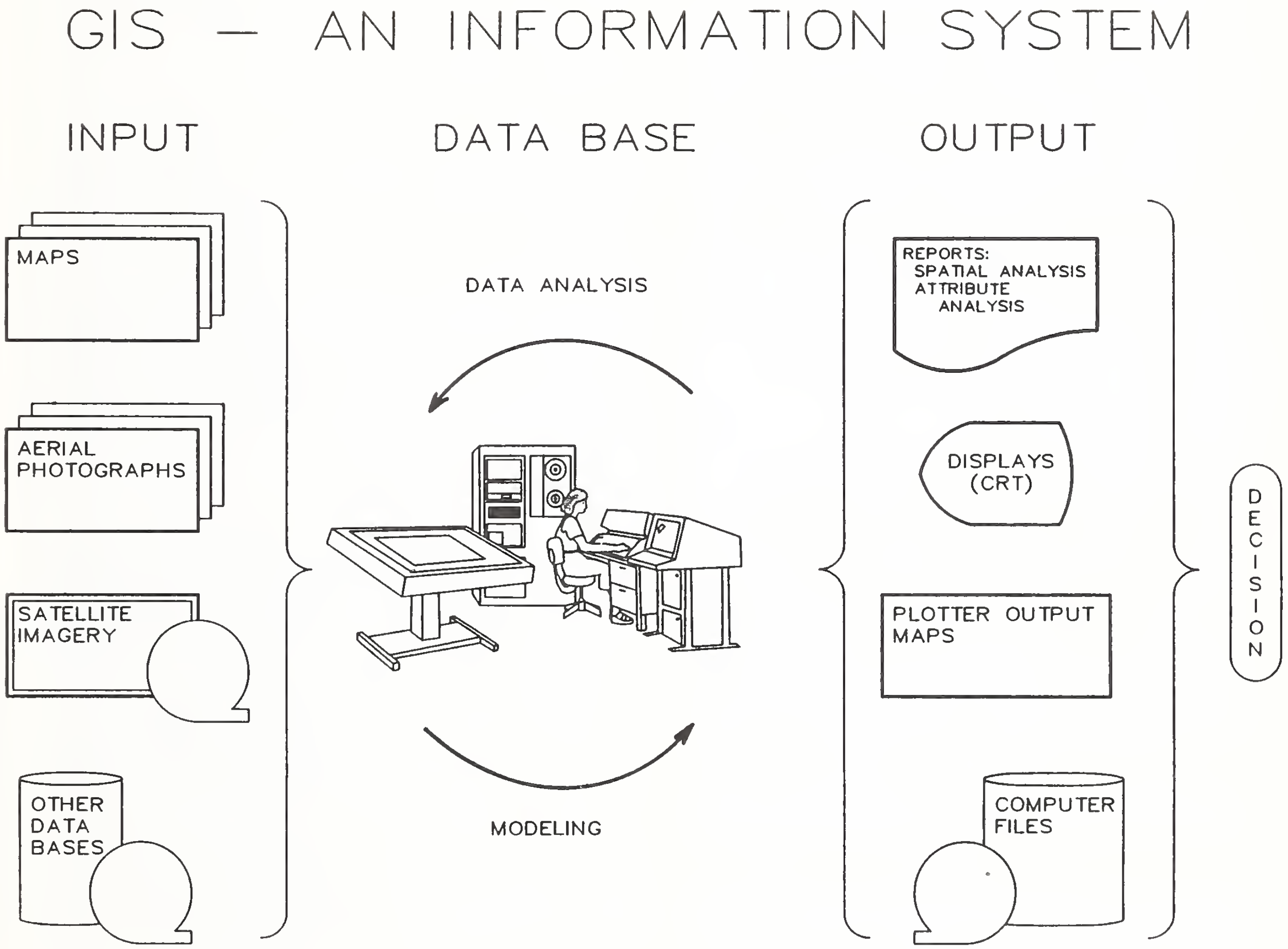

FIGURE 1. GIS - an information system.

Some of the operations that may be done on these layers are as follows:

- Create reports and lists.
- Measure numbers of items, distances, and areas.
- Calculate bearings, slope, aspect, and scale change.
- Interpolate heights along streams.
- Change or reclassify attributes.
- Generate polygons, corridors, perspective views, and cross-sections.
- Search by specific identifier or attribute, or within an area.
- Compare data sets.
- Perform contiguity and connectivity analyses.

Results of these operations are known as "interpretive information products" or simply products. These can be simple answers, graphic displays, or map-like presentations. These products are now done by manual methods; GIS should produce these more efficiently and cheaper. We anticipate that GIS technology will generate new information products, not producible by manual methods. Information products are then used by managers to make decisions. The most important part of the "system" is the human element. These are the people who make the computer tools that are easy to use and understandable, the resource specialists that understand the capabilities and limitations of the tools, and above all, the Forest Management Team that is knowledgeable of the new technology and willing to adapt it to meet their needs.

INFORMATION ANALYSIS - WHY GIS IS NEEDED

There is a sequence of events that usually occurs when a manager or a Forest Service group (Forest, Station, etc.) considers adopting new technology. This process, known as "information analysis," is necessary in order to determine what needs to be done, how often, and what tools are needed. Following is a description of the major components or steps.

Requirements

Let's take the job of a Forest Supervisor as an example. The Supervisor's job is to manage the Forest for the optimum combination of the following resources: timber, range, water, wildlife, minerals and water.

To accomplish this, the Supervisor needs certain information products, such as maps, statistics, and descriptions. The scope and complexity of the Forest Supervisor's job will determine what type of products will be needed, how many, and when needed. These questions are best answered by the Forest Management Team and representatives from each of the functional groups.

Information Products

Information products required for Forest management need to adhere to certain principles. They should be easy to use and understandable by the various groups in the National Forest or Experiment Station. Highly specialized products made for a single group cannot be easily shared with other groups. An important part of information analysis is to prioritize all the products needed at the Forest level and to find out when certain products will be needed. This results in workload over time required to generate these products.

Data

Information products are generated from data stored electronically in the database. The type and complexity of products will dictate what kind of data will need to be in the database. To produce consistent and reliable information products, we need a common structure for basic data, and a uniform terminology for its description. Basic data is what is directly observed or measured, such as tree species, DBH, and elevation. Such data has a much wider use (for more "functional" groups in the Forest), than does interpretive data. Some examples of interpretive data are habitat types, suitability area, and travel plan maps. Interpretive data is usually derived from basic data layers.

Technology

Tools such as GIS can convert data into information products. The complexity of tools obviously depends on their intended use. Intended use determines what type and how many products need to be produced and from what kind of data. It is important that GIS hardware, in addition to handling the job, be properly integrated with the existing Forest Service information distribution network. The key to

wide use is "user-friendly" software that does not require a degree in math or computer science.

The process of information analysis starts, therefore, with understanding requirements. What needs to be done with the information dictates what type of products, and in turn what type of data is needed. GIS technology helps convert data into usable and understandable products.

Information analysis is a vital planning step that should be performed by any Forest Service unit contemplating implementation of GIS.

ITEMS TO CONSIDER IN GIS IMPLEMENTATION

Structure of Database

Useful GIS operation depends on a properly structured database; it does not just happen. Database structuring is the most expensive and time consuming part of GIS implementation. Adherence to well-defined structure and standards is vital. Database structure refers to how the various layers are input and stored and how they relate to each other. Information Systems proposed the following four categories of data: location, resource, social and facilities (as described in Table 1). The Resource Information Project (described in the next section) investigated the structure for "Resource" data.

CATEGORY	STRUCTURE/ FEATURE	EXAMPLE
Location	Topography Landnet Boundaries	Elevation Township County
Resource	Permanent Transitory	Soil Type Watershed Veg. Species Fish Species
Social	Cultural Demographic Environmental Factors	Burial Grounds Population Endangered Species
Facilities	Transportation Site Features	Secondary Roads Open Pit Mine

TABLE 1. Possible structure of basic data

Sources and Standards for Data

Spatial or georeferenced data describing forest resources comes from many different sources, including maps, survey data (including Global Positioning System), aerial photographs, data from satellites, and many others.

To incorporate such a wide variety of data in a common database, it is essential to follow certain standards. The Primary Base Series (PBS 1:24,000 scale 7.5 minute maps) can provide the foundation for a database to which other layers can be tied and referenced. The Primary Base Series proposed as a foundation for GIS database is constructed to stringent Map Accuracy Standards. The layers in the PBS are: topography, hydrology, transportation, cultural features, landnet, boundaries, and land status. Although accuracy standards for resource and other data layers have not yet been defined, future users of GIS should be aware that GIS output is only as accurate as the least accurate input.

An important source for the base layers for National Forests is the Geometronics Service Center (GSC) located in Salt Lake City, Utah. GSC is charged with digitizing the base layers for all the National Forests over the next six years. Other data sources include the Regional Offices, U.S. Geological Survey, Bureau of Land Management, and State and local agencies.

WHAT IS THE FOREST SERVICE DOING NOW?

The concept of georeferenced computerized databases has been used in the Forest Service for many years. Many Forest Service units have been experimenting with the GIS technology for the past several years. The major effort currently underway is the Controlled Evaluation being conducted by Information Systems.

The following Forest Service units are participating: Tongass, Siuslaw, George Washington and Nicolet NF's, Northern Region (District level); Southeastern Station; and the Washington Office.

Both public domain and proprietary systems are being used in the Controlled Evaluation. This will result in a better definition of what the Forest Service needs, the contributions the new technology can make, and will assess the impact of GIS on the typical National Forest. Another national effort, just completed, is the Resource Information Project (RIP). The objectives of RIP were to survey a sample of National Forests and to investigate the kinds of

data that are currently being used to describe resources. The Resource Information Project provided important insights into the concept of "GIS corporate information structure."

Other applications of GIS are mostly project-specific. This usually means that data layers are collected and structured for a specific job or activity at the Forest, Station, or other unit. The "system" usually consists of a combination of Forest Service or other agency or university public-domain hardware and software. Several units, though, are using proprietory systems.

IMPLEMENTATION OF GIS

The implementation of GIS in the Forest Service is defined in the National GIS Plan (1988). The Plan stipulates that this new technology "shall facilitate the access, use, and sharing of management information about resources to help the Forest Service achieve its mission."

There are several components and action items defined in the National Plan that need to take place prior to implementation. These items deal with establishing an information base and structure, organizational readiness (awareness and guidance), technology procurement, and external coordination and oversight. The Plan indicates that the predominant technology applications will be at the field level of the National Forest System, Research and State and Private Forestry.

Implementation of GIS will include training at various levels, installation of hardware and software, and data acquisition and entry. Installation of GIS hardware and software will start in 1991.

REFERENCES

"National GIS Plan," USDA Forest Service, Washington, D.C. April 28, 1988

INTEGRATED FOREST RESOURCE MANAGEMENT SYSTEM (INFORMS)

William B. White and **John E. Heasley**

ABSTRACT

The **IN**tegrated **FO**rest **R**esource **M**anagement **S**ystem (INFORMS) is a decision support system for improving the utility of resource data and simplifying the use of new technologies in natural resource management. "Proof of concept" was evaluated on the Red River District of the Nezperce National Forest, Idaho, by integrating site-specific spatial and tabular resource data and eight response models into the INFORMS shell. Preliminary results were encouraging, with routine analysis taking several weeks to complete instead of several months.

INTRODUCTION

Resource management agencies in the United States have collected massive amounts of data related to complex natural management issues. As a result, conventional resource management tools and techniques have become less effective. Along with growing databases, increased demands on diminishing resources and an actively concerned public are forcing natural resource management (NRM) into the computer age. NRM is at the threshold of a profound transformation through the use of advanced technologies, such as geographic information systems, artificial intelligence programming, monitoring stations in space, and powerful computer work stations (Stock 1987; House 1983; Optiz 1986).

Practitioners differ, however, in their perception of the scope and of exactly how these new tools should be adapted to NRM. Some believe that expert systems, in the field of artificial intelligence, are the correct approach (Coulson and others 1987). Others suggest that GIS's or database management systems can be expanded to meet future needs (Burrough 1986). Still others see decision support systems or some combination of systems as the appropriate approach (Robinson and others 1986; Jackson and Mason 1986; McKeown and David 1987; Goodenough and others 1987). Roucher (1987) suggests we step back and take an entirely new look at information science in light of natural science needs.

While many of the advances in information technology have great potential, they are still too complex for NRM use. A key to successful use of new technology is the way it is packaged for the user. The slow acceptance of GIS in NRM can be attributed in part to the difficulty of use. New technology must be delivered in such a way that the manager is not burdened with the task of becoming a tool expert.

This paper describes the INtegrated FOrest Resource Management System (INFORMS), a system that integrates databases (spatial and non-spatial), spatial analysis functions, and simulation modeling with a central control module, creating an easy-to-use NRM problem-solving environment. Based on user query, INFORMS uses a mixture of systems operations and data to arrive at results, which appear to the user the same as if derived by more conventional means.

INFORMS ARCHITECTURE

The INFORMS concept was developed from an integrated and modular system called IPIAS (Integrated Pest Impact Assessment System) (Daniel and others 1984). To complement the Forest planning process, IPIAS addressed the problem of assessing the impacts of forest pests. It focused on developing a system that would integrate available tools to deal with the problem of forest pests. The principal components in IPIAS included a database manage-

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ment system, geographic information system, and several simulation models.

In addition to the underlying concept, this earlier project allowed the developers to formulate developmental guidelines that shaped the present system. INFORMS must:

- communicate in the same language (jargon included) as the user's
- produce the same results as the manual counterpart
- be modular, allowing new models or other components to be added as needed
- support decision-making, not make decisions
- be easy to use, not placing a burden on the user to learn a complex system

INFORMS reflects these criteria.

INFORMS is written in FORTRAN 77 and runs on a Data General MV series machine. In its present form, the software is made up of four major system components (Figure 1, next page). These components are central control module, model library, and spatial and non-spatial components.

Central Control Module

The central control module (CCM) is the primary component of INFORMS and operates as the logic engine of the system. The user communicates with the system via this component. User requests are transformed into system commands to define the problem, perform analyses, and present their results. The user interface is menu driven, providing both text and graphics capabilities.

The CCM is comprised of four submodules: project definition, analysis specification, analysis execution, and report generation (Figure 2, next page). The project definition submodule requires the user to define the spatial scope of the problem. A project area may be defined graphically by digitizing a project boundary or by selecting a group of spatial entities, such as stands, compartments, or watersheds, which collectively define a boundary. This boundary is used by the spatial component as a template to extract the spatial data required.

The analysis specification submodule helps the user separate a large problem area into logical components (sets of models) for individual study. Under each analysis, the user can further specify alternatives or sets of conditions under which the analyses will be run. This submodule also instructs the model library as to which models are required and specific data preparation programs to be run. Model input requirements are collated and redundancies removed to produce a user interface that is unique to each analysis.

Each analysis and its set of alternatives is executed by the analysis execution submodule. The user selects the time period to be simulated in this submodule.

The results of resource analyses are communicated to the user by the report generation submodule. The user indicates which analysis and alternatives are to be reported on, and the CCM invokes the output modules for the models that were run. Model outputs may be in tabular, graphic, or map form, and may be displayed on a terminal or sent to a printing device.

Model Library

The model library is a collection of programs (models) in files that simulate dynamics of various resources. These models consist of four interrelated modules: simulation module, data preparation module, and input and output modules.

The simulation module contains the equations and relationships that represent the observed natural phenomenon. This module also reads input information and stores simulation results for use by the output module or other simulation models. The data preparation module manipulates and transforms spatial and non-spatial data to a form required by each simulation model. The input module provides the interface to the analysis specification submodule through which the user specifies the simulation conditions (alternatives). The results of simulations are presented to the user via the output module.

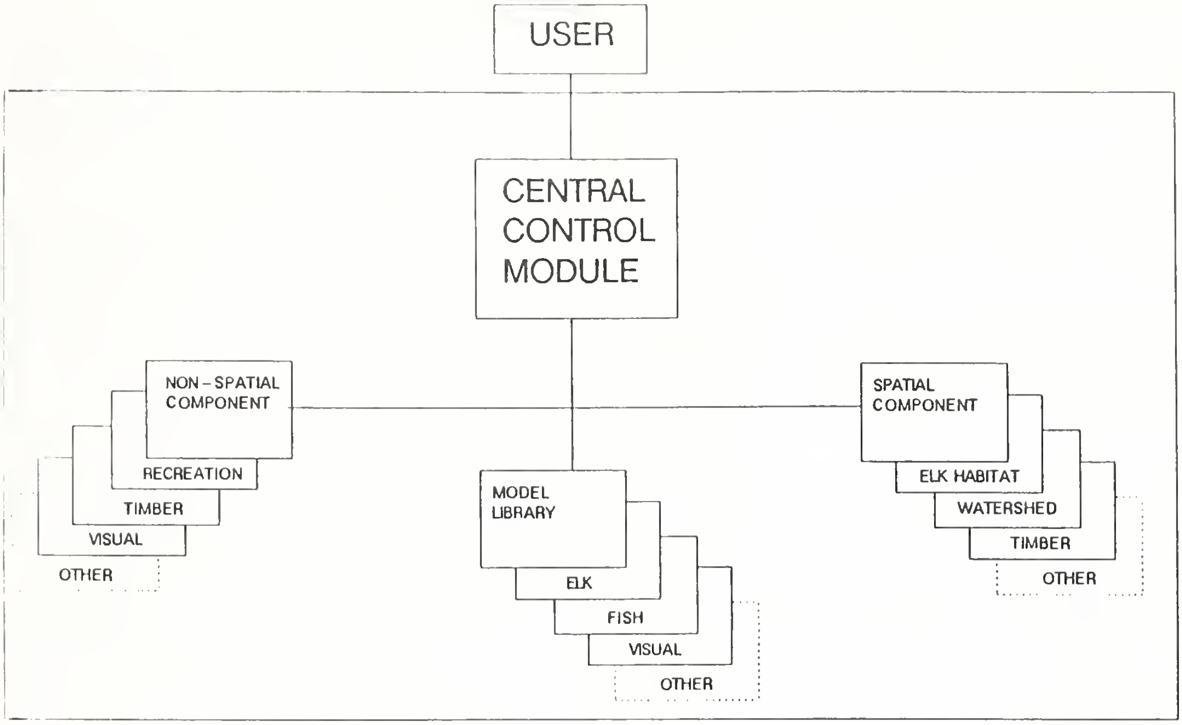

FIGURE 1. INFORMS diagram showing major components

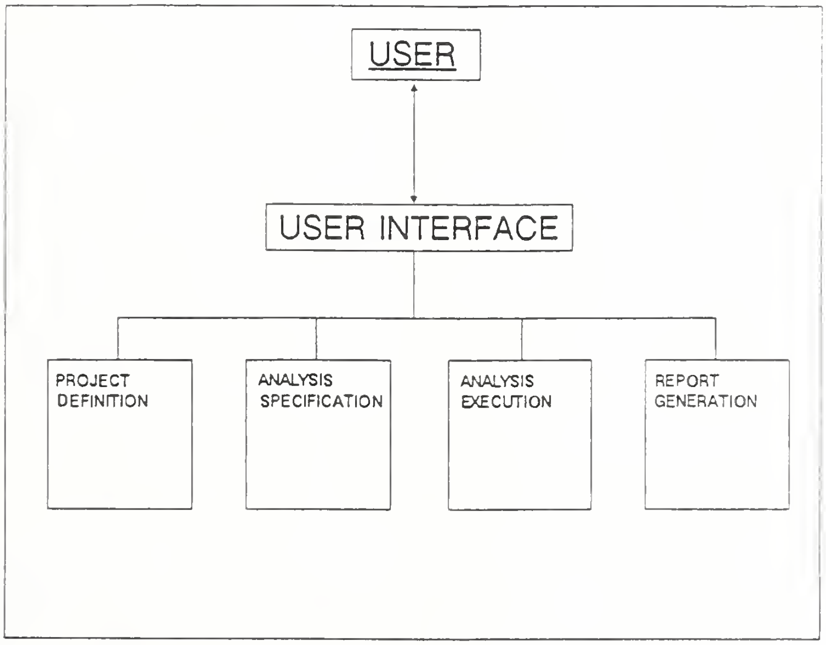

FIGURE 2. Diagram of Central Control Module

Spatial Component

This component contains the spatial data and the tools for manipulating and displaying that data. The spatial data are in the form of maps organized into various data themes, such as timber, watershed, soil types, and roads. Map information is stored in the polygonal format utilized by the general purpose Geographic Information System (GIS) Map Overlay and Statistical System (MOSS) (USDI 1988).

In INFORMS, spatial data must be transformed for use by the models and to provide the user with a visual reference for defining the spatial aspects of the problem. Linking to a general purpose Geographic Information System (GIS) is one approach. However, most GIS's contain many functions and related overhead not necessary to support INFORMS. Also, linking to a large, standalone system creates interfacing problems. These systems are designed to interface with a user, not with other systems. Therefore, INFORMS developers designed their own spatial analysis functions that complemented model requirements. The spatial functions contained in INFORMS include the following:

- Overlay. Computes the logical intersection (A and B), union (A or B), and difference (A not B) of two maps, and forms a resulting new map (Heasley 1988).

- Buffer. Computes buffer zones about points, lines, and polygons to form a buffer zone map.

- Area. Computes the area of polygons.

- Distance. Computes the distance between two points.

- Select. Selects specified map features by ID number or attribute name for analysis.

- Window. Sets the spatial scope of an analysis.

- Plot - plots a map on a terminal screen.

- Shade. Shades polygons with a specified pattern and color on a terminal screen.

- Highlight. Highlights map features specified by ID number or attribute name on a terminal screen.

- Label. Labels map features on a terminal screen.

- Zoom. Changes the size of the viewing window for displaying a map.

- Digitize. Allows the user to digitize map features directly on a terminal screen.

- Merge. Merges two maps to form a single map.

- Vectorize. Converts a raster map to vector form.

- Rasterize. Converts a vector map to raster form.

- Perspective Plot. Plots a three dimensional scene of a landscape as viewed from a specified viewpoint.

- Visibility. Highlights the areas on a map that are visible from specified viewpoints.

INFORMS also provides a direct link to MOSS. The user may access map making capabilities through this GIS. These functions are separate from those of INFORMS.

Non-Spatial Component

Only the source and structure of data in the non-spatial component is different from the spatial component. Non-geographic data, such as timber inventory data and economic data, are retrieved from various databases (local or remote). Within this component, non-spatial data are manipulated or transferred according to the input requirements of the models.

INFORMS APPLICATION

The Nezperce National Forest was chosen as the test site for INFORMS. The Forest had the individual components needed to test the integration concept, such as simulation models for individual resources, spatial data, and resource databases, and offered complex natural resource management problems. The Forest has 900,000 acres of commercial timber; it is heavily used by recreationists; there are large herds of elk and mule deer; it has two wilderness

areas, and on the Red River District, the study area, there is an impending outbreak of mountain pine beetle (MPB), *Dendroctonus ponderosae*. But the resource issue of greatest concern is the reintroduction of anadromous fish into the Red River.

Once abundant throughout the rivers of Idaho, chinook salmon, *Oncorhynchus tshawytscha*, and steelhead trout, *Salmo gairdneri*, populations were all but decimated by dam building on the Columbia River. Today the Forest is trying to re-establish these fish into historically used drainages, such as the Red River. Salmon spawning habitat is very sensitive; thus every action that creates sediment or affects stream cover must be carefully analyzed - a complex and time-consuming process.

On National Forests such as the Nezperce, resource problems are seldom solved with data from a single discipline. Similarly, resource problems are seldom solved using a single technology (White and others 1987). For example, predicting the impacts of a timber harvest might involve multidisciplinary data from wildlife, hydrology, fisheries, silviculture, and economics. The technologies or systems used might include a database management system, a geographic information system, simulation models, and perhaps remote sensing. Resource specialists from various disciplines use a combination of data and technology to estimate impacts. Individuals or multidisciplinary teams then collectively review all impacts to estimate cumulative effects. This approach is time consuming and requires the resource specialist to be a tool expert as well as a problem expert.

For this study, INFORMS was configured around general forest management practices, with specific attention to the MPB and anadromous fish problems. The present INFORMS also reflects many of the operational characteristics of the U.S. Forest Service planning and environmental assessment process. For example, INFORMS is presently designed to run analyses sessions based on emphasis alternatives biased toward an objective such as maximum fish protection or maximum economic return. Within each analysis, there can be several variations on the emphasis alternative.

INFORMS on the Nezperce integrates the following: a timber resource database, a spatial database (32 themes covering 20 1:24000 U.S.G.S. base maps), and eight resource response models. These models include:

- PROGNOSIS. A stand growth and yield model that simulates the size and structure of northern Idaho forest stands over time.

- NEZSED. A model that computes the amount of sediment delivered to critical stream reaches in response to logging and road building.

- FISH. A model which simulates the response of salmonid population characteristics to sediment loading in streams.

- ELK. A model that predicts the effect of road building on elk use in northern Idaho.

- COVER. A model that simulates the growth and structure of wildlife cover over time.

- CONTAGION. A model that predicts the spread and extent of mountain pine beetle damage in response to stand characteristics.

- DLOGPRICE. An economic model that evaluates the viability of proposed timber sale areas.

- VISUAL. A model that computes the visual sensitivity of an area and displays the physical results of management actions.

INFORMS resides on a U.S. Forest Service Data General minicomputer in the Red River District office. A high resolution graphics terminal is needed to take advantage of all INFORMS functions. For more than a year, INFORMS has been used instead of more conventional manual methods to help develop environmental analysis documents or environmental impact statements (EIS).

The Nezperce Forest Plan may call for the harvest of a number of acres of timber for a given portion of the Red River District. Resource managers must decide how, where, and when this timber will be cut. They also must consider the economic implications of the harvest sales, potential mountain pine beetle attacks, and the impact of logging on salmonid fisheries in the area. INFORMS has supported these types of analyses.

In tests on the Red River District, Nezperce National Forest in central Idaho, INFORMS provided positive results on the concept of integration. INFORMS was more than four times faster than conventional methods, provided more flexible and repeated problem solving, and allowed managers to simulate complex ecological interactions using a minimum of staff time.

SUMMARY

INFORMS can be used to help resolve complex natural resource problems more easily and efficiently, without requiring resource managers to become tool experts. By integrating models that simulate ecosystem interactions, managers were able to gain a better understanding of the interrelationships of the resources. With the increased speed and repeatability of INFORMS, managers "fine tuned" their decision-making. Designed primarily as an integrating shell, INFORMS assumes technology will continue to evolve, and allows for adaptation - an important feature.

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THE GEOGRAPHICAL RESOURCES ANALYSIS SUPPORT SYSTEM (GRASS) GEOGRAPHIC INFORMATION SYSTEMS (GIS) AND EXPERT SYSTEMS: EXPLORING THE POTENTIALS

Donal R. Myrick and Kenneth D. Shepardson

ABSTRACT

A grid-cell based Geographic Information System (GIS), Geographical Resources Analysis Support system (GRASS) uses a layered database, enabling complex analyses. Developed by the U.S. Army Construction Engineering Research Laboratory, GRASS is useful to resource managers in assembling sophisticated geographical databases for problem solving applications. Users can access, display, manipulate, analyze, and assemble multiple database layers from diverse sources. Additional capabilities are scanned imagery and user input and editing. Advanced technology updates in progress.

INTRODUCTION

The Geographical Resources Analysis Support System (GRASS) is an advanced Geographical Information System (GIS) developed by the U. S. Army Construction Engineering Research Laboratory (CERL).

GRASS was developed in-house by CERL to meet internal Corps of Engineering GIS needs. The development was started some ten years ago and has matured over the years through advancements in high technology and computer hardware and from the feedback gained from its application to many real world problems. Today it represents the best buy in the GIS community.

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WHAT IS GRASS

GRASS is a grid-cell based GIS that enables the user to assemble highly sophisticated geographical databases. The user can manipulate and modify the databases to meet his specific needs, perform complex data queries and analyses using the database, represent the results of these analyses graphically, and print a variety of reports and plots for reporting, archiving, and displaying requirements.

Since GRASS is a grid-cell based GIS, databases must either be generated in a grid cell format or converted to it. This format has numerous advantages and certain disadvantages. The disadvantages are simply that databases are memory intensive, and manipulation of the databases requires lots of computing power. Attaching attributes generally requires a new layer, with each cell requiring its own attribute entity. Fortunately, these disadvantages, which at one time were formidable, are rapidly being overcome by the tremendous computing power of today's graphic workstations. The advantages of grid-cell based GISs are largely associated with the ability to perform complex and diverse analyses on these types of database layers and with the fact that digital images, which are an extremely important source of data, are raster-based and can be readily converted to grid-cell format. The ability to perform diverse and complex analyses is a key capability, for without it a GIS is simply a map management tool.

Like all good GISs of today, GRASS uses a layered database and allows the user to stack together those layers relevant to his particular problem. The user may then interact with the database to accomplish the needed analyses.

GRASS TOOLS

GRASS provides the user with an enormous array of tools with which to accomplish his objectives. The GRASS tools are broken into essentially three types of commands: (1) the GRASS-Grid command, (2) the GRASS-Map Dev command and (3) the GRASS Imagery command.

The GRASS-Grid commands allow the user to display, manipulate, and analyze the database layers and to perform problem solving tasks. These commands provide the ability to combine layers, assign attributes and weights, calculate areas and distances, find coincidences, perform classifications and generate reports. There are some 95 sub-level commands in this command group to aid the user in performing analyses.

The GRASS-Map Dev commands are used to develop or assemble the graphical database layers. These commands enable the user to digitize data, edit data, and read digital geographic database files (DLG 3, DEM, etc.). The user can then manipulate the files in ASCII or binary format, make topologically correct DLG files, extract features, and convert to or from the grid-cell format used by GRASS.

A special addendum to the GRASS-Map Dev commands are the GRASS-Imagery commands. These commands allow the user to display, process, and georeference or register digitized Landsat or digitized high altitude photographs into a format usable by GRASS. The GRASS Imagery commands provide essentially the same image processing capability as the ERDAS package. They are user-friendly and powerful.

ILLUSTRATION

Perhaps the best way to demonstrate the diverse abilities of GRASS is through a simple illustration of how an analyst might use GRASS to address a resource management problem. Use of a GIS at this stage can help to identify the best alternatives, analyze these alternatives, identify the preferred solution, and provide detailed inputs for reports.

For this example, assume our objective is to locate a suitable site for a new recreation area and campsite. We can set forth criteria for suitability and use GRASS to identify appropriate areas for detailed consideration. From these identified areas, we can then identify development options that must satisfy additional criteria, such as minimum impact on natural resources. The foundation of criteria for "suitability" is a topic ripe for the application of AI, and GRASS is quite amenable to such developments.

For our simple example, we will use the Spearfish database, a sample database put together by CERL for demo purposes. The area is located near Deadwood, South Dakota and contains 33 separate registered layers. All of the layers were derived from different sources and brought together through GRASS into a single multi-layered database. Only a few of the layers will be used in our example.

Data Sources

The first step where GRASS is useful is in the assembly of the geographic data. GRASS enables the user to access data from such sources as:

- the USGS
- the Defense Mapping Agency
- Landsat multi-spectral scanned images
- thematic mapped images
- Soil Conservation data
- Forest Service data
- TVA
- Corps of Engineers
- data compilations of other GISs (Intergraph, Arc Info, Infomap, etc.) and data sets assembled for CAD applications, such as AutoCad.

The list of potential sources and formats that can be accessed is extensive and growing. Geographic data assembly is greatly enhanced by GRASS's open access.

Once the database has been assembled, the user may need to make his own additions. This may be accomplished by digitizing additional features using the GRASS MAP-DEV commands or by editing existing data constructs using the GRASS-Grid commands.

Sample Criteria

The next step is to formulate our alternatives. Here is where we begin to see the power of a GIS as opposed to simple map management software. Listed below is a a set of criteria which must be met by any area we are to consider for our site.

- location in a coniferous forest
- access by a major road
- Access/proximity to a stream
- Land gradient less than 12 percent

GRASS allows the user to formulate these criteria in simple logic constructs using the logical AND, OR, NOR, NOT, and IF statements and then to make the appropriate system calls and calculations to accomplish the selection.

In our example, we must first identify all of the population and development areas using the land-use layer. Using the COMBINE command, we apply a logical NOT to generate the unpopulated or undeveloped data layer.

The next step involves analyzing the geographic data layers to find areas that will meet our requirement. First, we can use the digital elevation layer from which slope has been derived to give us the slope layer. Again, we use the COMBINE to infract a new layer consisting of all areas with slope less than "12" percent. We then use the veg-cover and soils data layers to construct a layer for coniferous forest. In this case a lot of previous image work was done to classify the MSS image. Here reclassification is done to lump all non-coniferous vegetation into one group and coniferous into another.

The last step involves combining all of the new layers to create a layer that defines all suitable areas. The COMBINE command is used to accomplish this task. Once these areas are identified, the road and stream network can be overlayed onto the layer in a vector format. We can then choose the best of these areas as candidate or alternative sites for our recreation area.

GRASS SPECIFICS

GRASS is written entirely in "C" and operates in a UNIX environment. It is currently hosted on SUN, Masscomp, and VAX workstations, but because it it written in "C," it can and will be ported to other machines which support its graphics environment requirements.

GRASS is essentially a public domain GIS. It costs $200, and the Source Code for GRASS is provided. Thus, an experienced programmer can write specialized interfaces or device drivers (assuming the user has some requirement that is not already met by GRASS). The programmer can also develop specialized AI query or statistical routines that interact directly with GRASS.

For instance, at SPECTRUM we use Numonics digitizers, and for this product we had to write our own interface. This was a relatively simple task, since total access to the GRASS Source Code is provided. The National Park Service wanted to use an expensive VERSATEC electrostatic plotter, so they also had to write their own device driver.

CERL has a long-term commitment to the continued upgrade and support of GRASS. The GRASS documentation is outstanding, and numerous tutorials and educational opportunities are available. There is an active user's group and user's network so information exchange is easy and enthusiastic. A newsletter, appropriately called GRASS Clippings, is available. GRASS mail is also supported at CERL.

USERS

GRASS is currently in use by numerous organizations, including the DoD, National Park Service, universities, NASA, National Research Corporation's Bechtel, and private companies. Virtually all of these user entities are making contributions to expanding the capabilities of GRASS. As these improvements become available, CERL will almost certainly include those the user network requires. GRASS development has been very user-oriented.

FUTURE

Where is GRASS going in the future? As access to data resources becomes more extensive and the resource management problems become more complex, the setting of criteria and developing sets of sophisticated database queries becomes quite complicated. This opens the door quite naturally to a more extensive use of AI procedures and expert systems to aid the analyst. Already, GRASS has a built in inferential engine (GINFER), which is a rudimentary AI that will be enhanced by CERL in new releases of GRASS. Furthermore, NASA Johnson Space Center has developed a "C" language program system called CLPS, which is a Unix-compatible AI system that appears to have great promise. It also is public domain software and is

available for the cost of distribution. Several organizations are currently using CLPS to enhance the AI capabilities of GRASS, and we will see more of this in the future.

Other areas where we will see enhancements in GRASS are the same as we will see in other advanced GISs. There is a move to develop a standard geographic interchange file system like that used for digital drawing interchanges between CADD Systems, such as IGES. This geographic standard file system will most likely be a standardization of the DLG3 format. When this is available, everybody can write conversions programs for translating their system files to and from the standard file format. Currently, we have many such programs to access everybody else's formats, but when an enhancement is implemented, or a new file developed, a new program has to be written or at least modified. Standardization will go a long way toward remedying this problem.

NEW TECHNOLOGIES

New technologies dealing with scanners and remotely sensed images will continue to have a great influence on GRASS. Version 3.0 of GRASS will have increased capabilities to deal with remotely sensed data. These capabilities currently reside primarily on the MassComp. The new release will make them also available on the SUN. Some impressive capabilities are being demonstrated that use the currently available high resolution drawing scanning devices. These devices are only getting better. New techniques decrease both the time and cost associated with the assembly of high fidelity databases; the most expensive and time consuming part of using a GIS. The GSC is generating high quality maps, but the data are not all in digital formats. Scanning will make all of the GSC products available for use.

And last, in the areas of map production, new plotter drivers are constantly being developed. These range from the low-end dot matrix printer/plotters through the laser and high resolution ink jet devices to the high-end Versatec's and Calcomp electrostatic devices. Quality of output is strictly a matter of budget. GRASS is a GIS that lets you invest in hardware, because the software is essentially free. We feel that GRASS should be a part of every resource manager's tool box.

UTILIZING EXPERT SYSTEMS AND GEOGRAPHIC INFORMATION SYSTEMS IN FOREST PLANNING

Margaret M. Watry

ABSTRACT

The National Forest System is required by law to develop, implement, and monitor Land and Resource Management Plans. The Eastern Region has developed an integrated process to implement the Forest Plans that are completed. The Nicolet National Forest is utilizing the technology of a Geographic Information System and an expert system to develop a tool to make this process work.

INTRODUCTION

The National Forest lands have a wealth of resources and a high demand for their many uses. Public land managers must provide for these uses while maintaining a healthy forest. Issues surface each day, requiring us to re-evaluate how we currently manage this land; concerned publics with widespread interests want to know what we are doing. We rely on databases that store an inventory of the resources in data form to address these concerns. This information is in great demand for day-to-day management of the Forest and also for long range planning.

The Nicolet Forest Plan is the reason for many of the projects that are now underway on the Forest. To analyze management regimes presented in the Plan, we had to consider the spatial relationship of the resources. In the past we hand-colored maps. Then we got fancy and made transparent overlays to enable consideration of more than one idea at a time on one map. One limiting factor in this process is not the amount of data but the ability to mentally organize and compare the information from all the resources. The other limiting factor is the availability of data; many resources are not yetcoded into databases. Currently most of this information is stored in separate unrelated databases, making its use in day to day and long range decision processes awkward and complicated. Extracting and analyzing resource information from these different data sources can be frustrating, time consuming, and expensive. Consequently, managers may find themselves in a "catch 22" position where they cannot afford to use all of the available information but by law will be accountable if they do not. Fortunately, the common characteristic of all resource data is that it is tied to a location on the ground. Therefore, a Geographic Information System (GIS) bridges the gap between identifying the location and actually mapping the location. A GIS can store, organize, retrieve, and analyze data according to spatial relationships.

USING TECHNOLOGY IN FOREST PLANNING

At a crucial time in the planning process, Forest Pest Management Methods Application Group (FPM-MAG) and the U.S. Fish and Wildlife Service visited the Forest with the concept of using a GIS. Their intention was to provide a way to track spruce budworm infestation on the Forest. The Forest saw a valuable additional use for land management planning and took the risk of buying into it. Beginning in 1983, the entire Forest was digitized into 28 layers of data that represented the information needed to manage the Forest. Among other considerations, these layers include the following:

- Political boundaries
- Land ownership
- Vegetation
- Soil types
- Roads

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- Trout streams
- Wood duck boxes
- Cultural resource sites

The Nicolet is using the Map Overlay and Statistical System (MOSS), which is a public-domain geographic information system currently being maintained by the Bureau of Land Management (BLM) and Technicolor Government Services (TGS) in cooperation with Autometric, Inc. and the U.S. Fish and Wildlife Service.

MOSS was designed to provide nontechnical users with the capability to retrieve, analyze, and display maps and other spatial data that are stored in the system. This tool has been used for planning, impact analysis, wildlife habitat evaluations, and project planning. Four District Offices are equipped with graphic terminals and plotters in addition to the Supervisor's Office, and Forest personnel have been learning to use this tool for management purposes. Learning another system has compounded their frustration. Too many separate information systems actually complicate Forest management efforts.

Two years ago, FPM-MAG and the U.S. Fish and Wildlife Service again visited us to consider using Expert System technology in combination with the GIS. The selling factor for this case was that expert technology could automate the interface between existing databases into one computing environment. Not only would an expert system bring together the databases, but it would also store knowledge from specialists and information from Forest Service handbooks. Again, they suggested application to a pest-related problem, but the Forest deviated slightly by developing an expert system for aspen management.

ASPENEX was an expert system designed to prioritize aspen stands on the Forest for maximum benefit to wildlife, timber, and recreation. Rules were developed to support the silvicultural guides for aspen, habitat requirements for ruffed grouse and white-tail deer in aspen, logging specifications, and recreational considerations for this forest type. These rules could then mimic the Forest managers' analysis processesfor evaluating aspen stands for determining what type of management they should receive. The field expert could use this guided information as the basis for making a decision as to how to implement the management guides in the Forest Plan for aspen areas. The decision could be supported by thorough documentation at the touch of a finger. This system was never fully developed because of a bigger concern that was demanding attention on the Forest. The Region was working on ways to implement the Foest Plan. They designed a process that would force integration of resources and projects.

Integrated Resource Management (IRM) is Region 9's approach to Forest Plan implementation. The IRM approach and principles are not a new concept. We will plan around the Forest Plan goals and objectives in an integrated manner to achieve a balance in multiple uses of the Forest. The areas being analyzed are larger, the issues seem to be getting stronger, and the time needed to fully analyze these areas is overwhelming.

Viewing these problems, District Office personnel thought to bring the technology of a GIS and an expert system together for decision making. Consequently, the Integrated Resource Management Automation (IRMA) project is a system being developed to bring these advanced technologies together into one computing environment.

The IRMA software system brings together existing databases and expert system shells into one integrated Decision Support System. A system such as this can mimic the human thought process during the analysis for Forest planning. Utilizing information contained in current databases combined with Forest Plan information and user input, the system will enable Districts to readily explore and assemble alternative arrangements of the desired future Forest condition and select the one that best complies with the National Environmental Policy Act (NEPA) and gives the greatest net public benefit. IRMA will assist the Interdisciplinary Team in evaluating these alternatives by retrieving data stored in numerous databases and, with the aid of an expert system, evaluate them against user input criteria. The result of using a systematic approach will be the ability to document the reasons for and the consequences of management decisions. This evaluation and documentation is required by NEPA.

IRMA will offer several significant advantages to resource managers:

- All relevant information for Plan implementation will be in one place.

- A reasonable number of alternatives can be considered with the same intensity while realizing labor and dollar savings over manual techniques.

- All results are written by the Forest and can be adapted to the other needs of Integrated Resource Management.

IRMA will be user friendly, all technical parts will be transparent, and the user will need to know the language of only one computing environment. Window software will be used with pull-down menus so the District user can do more than one task at a time on the screen. Integrated resource projects will require looking at information from different data sources; therefore, multi-tasking will be critical. The rulebases will house the judgmental rules from the Forest, such as restrictions near threatened and endangered species, stands' susceptibility to insect and disease problems, equipment restrictions on the different soil types, recreational considerations for different vegetative types, habitat requirements for all the management indicator species, etc. Rules will also be coded to depict the standards and guidelines addressed in the Forest Plan and Environmental Impact Statement. Having these rules entered into a system such as this will allow the user to effectively analyze the management for any given acre of land. The system will guide the user through all the applicable rules for that management area. Specific details in any document will not be forgotten but will be systematically reviewed. The user will be able to interact with these rules for any specific consideration. IRMA will guide the user in making the best decisions possible and portray those decisions to the public in an intelligent and understandable manner.

CONCLUSION

The Nicolet IRMA team has been working under the guidance of Bill White (WO-FPM-MAG), Brad Gilbert (WO-LMP), Patrice Janiga (National Computer Center), and Paul Kihlmire (R9-Planning, Programming and Budget Staff). Communication has been maintained with WO-Information Systems, WO-Timber Management, Lake State National Forests, and the U.S. Fish and Wildlife Service. This project has widespread national application in many aspects of information sharing and natural resource management, and it will continue to involve a variety of people to keep this perspective. Those who have seen its capabilities just in the prototype, specifically our District people, are anxiously waiting to use it.

Forest planning is becoming more complicated as the public is becoming more involved in and knowledgable of what we are doing. The Forest Service needs to defend sound resource decisions through information. Bringing the technology of GIS and Expert Systems together with the existing databases will provide a way the Service can more effectively implement these Forest decisions.

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APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS IN WILDLIFE RESEARCH

L. Jack Lyon

ABSTRACT

Geographic Information Systems (GIS) expand wildlife research techniques, allowing new approaches to evaluating habitat selections by individual animals. GIS databases increase the reliability of wildlife habitat models. Development and testing of habitat simulation models can be based on direct evaluation of habitat selections under stress and on configuration of habitat structures within home ranges. Wider GIS availability will expand wildlife research to examine cover-type coincidence, patch dynamics, habitat fragmentation, and other questions.

INTRODUCTION

The Geographic Information System (GIS) is one of the most exciting land management tools to appear in recent years. Maps have always been an integral part of land management, but the management of maps has always bordered on chaos. In working with various National Forests and Ranger Districts, I have harbored a secret envy of the neatly organized files of maps and photographs, compartment and subcompartment files with overlays, and other visible evidence of competent organization. Researchers in general, and this researcher in particular, rarely approach anything comparable. And yet, I have not often encountered two Ranger Districts, even within the same National Forest, using identical systems. Despite the outward evidence of organization, I suspect many managers find, as I do, that it does not require much of a pile of maps, aerial photographs, and overlays to present an overwhelming obstacle to orderly progress.

Will GIS solve this problem? Interestingly, "getting organized" is not usually mentioned as one of the things GIS does. However, the tour of the Geometronics Service Center here in Salt Lake City, and the presentations today and tomorrow, should not leave much doubt. Simple sorting and filing, when vast amounts of information are involved, is a formidable task. GIS has the potential to reduce that task to reasonable proportions.

GIS--WHAT ELSE DOES IT DO?

If getting organized was the only function a GIS provided, it would be worthwhile for some of us. However, GIS can be far more versatile. According to J. Berry (1986), "The processing functions of these systems can be grouped into four categories: computer mapping, spatial database management, spatial statistics, and cartographic modeling." Other speakers in this seminar will address these functions as applied to management, but I mention them here because the applications in research can be somewhat different.

Computer Mapping

Conventionally, maps are used to display land ownership, contours, cover types, habitat types, soil types, roads, and a host of other features. A conventional printed map, however, rarely presents more than two or three kinds of information, and when the desired combination is not available, some compromise using overlays is required. Maps stored as computer files offer the advantage that each feature of interest can be stored as a separate file. Thus, all possible combinations of information are readily available, and the user can easily tailor a new map in any desired combination.

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Spatial Database Management

Summarization of computerized map data within GIS continues a traditional use of maps. In this application, a functioning GIS will not do anything that is not already being done some other way--but it will do it with incredible speed and without making errors. A map file that requires little physical storage space and can be easily updated has obvious management advantages. New roads and cutting units, fences, campgrounds, and other changes can be entered in the data files as they are created. Properly maintained computerized maps are always current.

Spatial Statistics

Among the less traditional techniques that have become available with GIS is algebraic or mathematical analysis of two or more map surfaces and generation of descriptive statistics. GIS commands that allow identification of spatial coincidence, juxtaposition, optimal paths, and proximity have introduced a whole new potential in evaluating resources on the land.

Cartographic Modeling

Finally, the display of map surfaces resulting from spatial analysis provides visual and conceptual opportunities that have not been envisioned or exploited in the past. Three-dimensional contour maps of the land surface are not unusual, but GIS makes it possible to display three-dimensional maps of fire danger ratings, recreation accessibility, and wildlife habitat quality that add whole new dimensions to managerial and research capability.

APPLICATIONS TO WILDLIFE MANAGEMENT

The potential of GIS in environmental analysis seems almost endless. The manual for GEOSCAN (1984) is direct and pragmatic in describing a program written specifically to handle animal-habitat data for a state game department: "The habitat variables governing the distribution of big-game animals may be divided into three main classes: site-specific, site-adjacent, and behavior-related." The user's manual for pMAP (1986) indicates more generic capabilities such as measuring boundary configurations, the ratio of area to edge, frequency of interior gaps, coincidence, juxtaposition and diversity, distances and connectivity, shortest paths, least-resistance paths, and viewing areas. All this is in addition to producing statistics like mean, median, and mode for any desired set of data.

With such capabilities, GIS appears a sure winner. At present, however, the most widely utilized capability of GIS is inventory control. As applied to wildlife, this usually means maintaining records of habitat quality or quantity over space and time. Data describing the entire Tongass National Forest in Alaska, for example, are being digitized. The resulting summaries will be used to maintain inventories of wildlife habitat for forest planning (Suring and Sidle 1988). At the broad levels required in planning, the habitat categories used represent a major improvement over past methods. At the District or project level, however, there is a substantial difference between interpreting inventory data for timber and wildlife applications. A forested acre with basal area of 240 ft^2 has a fairly exact meaning in the timber inventory. For wildlife it might indicate big-game thermal cover, goshawk or boreal owl habitat--or maybe nothing at all.

The essence of habitat evaluation for wildlife is that the combinations are more important than the parts. A forested acre cannot be evaluated in isolation because adjacent acres may add to, or detract from, wildlife habitat values. This interdependence has created an especially difficult problem for forest planners working with linear programming models. Commodity outputs for timber and range can be reasonably modeled on a per-acre basis, but amenity outputs, like wildlife, requiring specific areas for assessment and constrained management to meet objectives are not readily susceptible to linear programming (Cissel 1984). Where planners have recognized the necessity for assessment of contiguous areas, alternative solutions have been worked out--usually at some compromise in cost and additional analyses (Cissel 1984). In many forest plans, wildlife habitat is represented by dummy variables and habitat evaluation is actually completed outside the planning model.

With a functioning GIS, assessment of contiguous areas is not only possible, it can become relatively easy. Even in the absence of widespread GIS capabilities, wildlife biologists have become adept at creating habitat evaluation models that utilize the concepts of GIS. The Fish and Wildlife Service

promotes Habitat Evaluation Procedures (HEP) to produce Habitat Suitability Index (HSI) models, the Forest Service has Wildlife and Fisheries Habitat Relationships (WFHR) models, and many other techniques have been developed (K. Berry 1986). Whatever the acronym, the basic concept hinges on the assignment of suitability indexes or utilization coefficients to plant communities. In virtually all cases, a geographic information database is a logical starting point for input to these models.

If all this sounds too good to be true, why are we talking about it instead of plunging ahead? The best reason, I think, is that many descriptions of GIS really are too good to be true. GIS, in my experience, is virtually always described glowingly for what it will do, while the significant problems are mentioned only after the product has been sold. I have heard Forest Service computer experts discuss these problems several times, and I know they will be discussed again in this seminar. Nevertheless, it is worth emphasizing that GIS is not perfect.

The two GIS problems that influence wildlife research and management the most are the cost of creating an adequate database and model reliability. Devine and Field (1986) may not have been the first to notice, but they say it very well, "...digitizing...is a slow, agonizing, and extremely costly process...." This statement hardly needs expansion, and I know it will be reiterated during this seminar. Tomorrow, several presenters will describe the use of Landsat photography to circumvent the agonies of digitizing, but I doubt any of them will try to convince us the costs are not significant or that Landsat produces no agonies of its own.

The expense and difficulty of creating a database is only the beginning. The majority of land-use applications require at least a minimal confirmation of vegetation structure with ground-truth data. The information needed for wildlife habitat management often requires much more than minimal confirmation. A single example will demonstrate. When Landsat signatures are properly identified, it is easy to differentiate meadows and clearcuts and to differentiate between young timber stands and older stands. In many cases, it has been possible to identify different tree species in forest stands. For timber management, fire management, or range management, this level of information may prove to be adequate. However, most wildlife species live beneath the tree canopy, and the information describing understory structure, snags, and down logs is almost always missing unless ground-truth sampling has been extensive. As a result, it may not be possible to utilize an existing database in an effective manner.

The other problem in wildlife management is model reliability. For a brief period last year, I thought this problem was unique to wildlife, but it is manifest throughout all phases of resource management. Garland (1988), in an opinion column in a recent Journal of Forestry, provides strong indictment of models when they:

- are used inappropriately in natural-resource decision-making,
- are used outside the range of data for which they were built,
- have not been validated or thoroughly tested for consistency,
- fail to identify the assumptions upon which they are dependent,
- are built by picking and choosing relationships out of thin air,
- invite overextension of model outputs,
- oversimplify complex relationships,
- and (worst of all) when they leave the impression that anything done with a computer must be correct.

It seems unnecessary to embellish a critique that comprehensive. The only point I believe he missed is specific mention of the shortcut from model development to management application. The history of wildlife habitat models, and many other models, I suspect, is that the need for research is recognized after the model is already in use. And, the more complex and useful the model seems to be, the more reality weighs against the possibility of any large-scale validation. Where wildlife habitat models of great complexity have been developed, few scientists believe that sound research can be conducted at the experimental level required for validation. Validation, particularly over a large geographic region, requires far better wildlife

census techniques than are currently available for the majority of species.

RESEARCH APPLICATIONS

Building and verifying realistic wildlife habitat models is, I believe, the most obvious and important application of GIS in wildlife research. At least three approaches can be suggested. The first, and probably least desirable, is direct verification and restructuring of existing models. When no more than a half dozen variables are involved, this is a usable technique. O'Neil and others (1988) have shown that a literature-based HSI can be field tested against expert evaluations of selected habitats and the model appropriately restructured to improve performance. The method they describe, however, still depends on the subjective judgment of experts, which is very often the basic problem with model performance in the first place.

When wildlife census information is available instead of subjective evaluations, verification can be very powerful. Donovan and others (1987) provide an example in which an HSI model is tested by comparing random locations against verified turkey home ranges. In their study, the model performed fairly well because the turkey is a habitat generalist for which "...the specific habitat requirements of the wildlife species can be associated with GIS-measured variables...." These authors point out, however, that other wildlife species may require more highly refined variables in the GIS data. The information required for testing wildlife habitat models of small birds (Verner 1980), or bobcats (Lancia and others 1982), or antelope (Cook and Irwin 1985) might include variables that would not normally be expected in a general-purpose GIS database.

If wildlife habitat models are to function with accuracy, they should be built on data derived from studies of seasonal habitat selection, specific daily stress, physiological or behavioral requirements, and responses of animals to identified stress conditions. Although it has sometimes been possible to obtain adequate numbers of animal-location observations for this kind of research, obtaining comparable numbers of habitat-data samples has been logistically intimidating if not impossible. Habitat information has been obtained by extrapolation from aerial photographs or by sampling small plots in the field. The most widely used analysis is comparing habitats at recorded locations with habitats at random points (Marcum and Loftsgaarden 1980).

Sample sizes for use and availability analyses are easily increased where a GIS database is available. More important, the ease with which usable data can be obtained in a GIS system will probably lead to major revisions in the structure of the analysis. Sampling of areas as large as a daily home range has generally been considered impractical. As data for more areas are digitized and become readily accessible through GIS, more complex habitat descriptions over larger areas will become commonplace. Comparison of daily home ranges to randomly selected areas of the same size should almost totally replace analysis of point samples.

Additional research opportunities that will be enhanced by the existence of a GIS database will include studies evaluating habitat selection in response to seasonal or specific stress situations. One approach is to evaluate the habitat structures accessible from each animal location in a discriminant function analysis. This is a surprisingly powerful method of separating seasonal habitat selections or selections made as a result of an identified stress response (Servheen and Lyon 1989). After the necessary habitat structures have been identified, they can be built into a wildlife habitat model. The obvious advantage of this approach is that wildlife habitat models can be built from the bottom up, using the two or three most important habitat variables. Sequential testing of additional variables, as added, provides an opportunity to evaluate model sensitivity and accuracy of prediction.

A second approach provides somewhat less flexibility in sensitivity analysis but has the advantage of assured completeness. Instead of sampling the area immediately available to an animal, the investigator can consider all locations in an animal's home range. Hewitt and others (1986) used this technique, coupled with Landsat imagery, to determine that spotted owl breeding territories averaged 68 percent old growth. For wildlife species with complex habitat requirements, it may be possible to identify combinations of habitat components that must occur in appropriate juxtaposition. Unless the species being studied demonstrates very high adaptability, essential habitat variables will be common to all home ranges--thus providing

descriptive input for building a wildlife habitat model on objective and unequivocal data.

Where GIS is available, studies involving quantitative evaluation of edge can be completed with far less effort than Schuerholz (1974) required using aerial photographs. At the University of British Columbia, research is already being done in computer analysis of distance from edge as a variable in habitat use by deer (Viremsater 1988).

SPECULATION

Control of landscape inventories with GIS will provide both research and management with a tool of great power and diversity. Research applications already described in this paper are essentially extensions of existing research techniques using the obvious power of this efficient tool. However, a whole new field of landscape ecology has developed on the strength of GIS capabilities, and I believe we will see the development of new approaches to wildlife research as well. In some respects, speculation about the potential of GIS in wildlife research is a little like writing the script for a Buck Rogers adventure. We do not really know what is possible, but as the tool becomes more widely available, new uses will almost certainly be developed. In the near future, I expect GIS to produce a quantum jump in logic so that research hypotheses testing edge effects in wildlife habitats will be framed around diversity and juxtaposition rather than linear concepts. Juxtaposition, in particular, has been the buzz word of wildlife management for over 40 years, but learning to spell it has been a greater accomplishment than actually using it in applied habitat management.

Other approaches to habitat evaluation, using concepts related to pattern recognition (Williams and others 1978) should become more important. For example, Alaska, Douglas (1988a, 1988b) has been able to utilize GIS to identify topographic configurations that will assist caribou in avoiding or surviving insect attacks. Similar methods for identification of big game winter ranges, bedding sites, calving areas, and wallows could be used in ways only partially visualized at this time.

The capabilities of GIS in producing mathematical representations for area-to-edge ratios, cover-type coincidence values, expressions of connectivity, path configurations, and barrier analysis will suggest analytic techniques not now in use. Questions involving patch dynamics, habitat relationships and processes, organism responses at different spatial and temporal scales, and habitat fragmentation will be addressed at a conceptual level not now apparent.

Virtually every biologist who has used a GIS system or seen one in use has been enthusiastic about the potential. I do not believe that enthusiasm is misdirected. However, maximizing GIS as a management and research tool will require continual communication of both successes and failures as well as coordination of effort.

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APPLICATION OF GIS TOWARD EVALUATION OF HABITAT SELECTION BY KAIBAB MULE DEER

Dennis D. Haywood

ABSTRACT

ARC/Info residing on the Arizona Land Resource Information System (ALRIS) was used to conduct an investigation of summer habitat selection by mule deer (*Odocoileus hemionus hemionus*) of the north Kaibab plateau. The software allowed statistical sampling of vegetation in relation to deer locations, and allowed statistical comparisons. Deer were shown to select areas of vegetation diversity, primarily consisting of pine-mixed conifer-meadow-aspen.

HABITAT SELECTION

One of the basic problems facing wildlife biologists is to determine whether a species of interest is actively selecting a given habitat type. If the researcher can show that a species is selecting a certain habitat type, then resource managers can opt to manage for an increase, decrease, or maintenance of that habitat with the goal to increase, decrease, or maintain that species' number. While this question is basic and easy to pose, it may not be an easy one to answer.

Early definitions of habitat selection by Ivlev (1961) and Edmonson (1971) were based on the concept of forage ratio. Forage ratio is the proportion of a food type in the diet compared with the proportion of that type in the environment. For example, if 75 percent of an animal's diet consisted of Aspen leaves, and yet Aspen composed only 10 percent of the vegetation in the environment, then use exceeds availability, and active selection is occurring.

The first difficulty lies in determining precisely how much of any food type an animal consumes. However, the amount of time an animal occurs in a given habitat type can be used as an index to the relative importance of that habitat. The assumption is that if an animal spends a disproportionate amount of time in a certain habitat type, then there is a component (which may not even be measured) that is required and essential to sustain its life.

The second difficulty is that measures of this type are greatly biased by what the researcher includes in the list of available components. For example, Johnson (1980) indicated that a researcher may not believe a food item to be valid (perhaps it is ingested accidently while it consumes other food), and may exclude it from consideration. Such a choice could change a preferred food item to being considered avoided. Likewise, the researcher must choose spatial bounds to the environment that is available to the animals. Erroneously choosing a large area (in excess of that which the animal may travel) could show quite different proportions of each habitat available than would be derived by choosing a small boundary. Study boundaries are quite often arbitrarily chosen and used to define what is available to the animal. Proper choice of the area that is "available" to the animal under consideration is an important step in any analysis of habitat selection.

GIS Techniques

In this study, one objective was to determine if Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) on the Kaibab plateau during summer (June 4 - October 28) actively select for any vegetation type or association of types. In consideration of the pitfalls in habitat selection analysis previously mentioned, GIS capabilities were employed to investigate its usefulness.

Collection of data began in 1978 and continued until 1981, when 115 deer were captured by means of drive nets, box traps, and rocket or cannon nets. Each deer was equipped with radio collar telemetry

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unit. Deer were located aerially with a radio tracking system consisting of directional antennas mounted on the aircraft's struts and belly. Locations of each deer were drawn on U.S.G.S. 15 minute topographic map with an accuracy estimated to be within a given quarter section. UTM coordinates were then derived from the 15 minute quad, and interpolated to 0.1 km. Coordinate data were input to ARC/Info on the ALRIS Prime 9950 to create point topology. Observations ceased at the end of 1984, or upon radio failure, natural mortality, or harvest of telemetered deer. EAch deer was located approximately once each month, for a total of 3,912 locations.

Vegetation type maps were digitized also via ARC/Info. The vegetation was divided into sixteen classes or forest timber types as defined by U.S.F.S. timber compartment maps, Kaibab National Forest. This same classification was used in digitizing type maps of the Grand Canyon National Park, which were provided by the Office of Arid Land Studies, University of Arizona.

A one square kilometer grid was created with the **Generate Grid** function of ARC, which covered the whole Kaibab Plateau. The **Identity** function was used to overlay the master grid on the vegetation cover. As a result, each grid cell contained a network of vegetation polygons. Areas of multiple fragmented polygons of identical vegetation types were summed by using a small Info program. The final product was a data file that contained a grid cell I.D. number, and areas of each vegetation type occurring within that grid cell.

The **Identity** function was used once again to associate each deer location with the master grid cell I.D. number where that deer was found. The result of this process was a data file, which contained a deer's I.D., date of observation, location, and areas of each vegetation type within a 1 km^2 sampling quadrat where that deer was found.

An equal number of uniform random locations were computer generated and analyzed in a similar manner. Areas of each vegetation type within a quadrat (or grid cell) containing a random point were recorded. This allowed comparisons of vegetation use between random and actual deer locations both in terms of simple frequency of occurrence, and frequency of occurrence by area.

Statistical Analysis and Results

The resulting data from associating deer and random locations to vegetation with ARC/Info were provided to SPSS statistical software. Analysis was based on the hypothesis that Kaibab deer utilize habitat in proportion to its availability. Table 1, next page, presents a comparison of frequency of use between observed and random locations. In general, use is proportional to availability; however, several important deviations are noted. Pine and mixed conifer are significantly selected, while spruce-fir and pinyon-juniper classes are significantly avoided.

The question then arises whether or not deer habitat utilization is related to associations of vegetation classes occurring within the 1 km^2 sample quadrats. Table 2, next page, presents frequency of pairwise vegetation associations used by Kaibab deer. Notice that this table contains information only for those classes identifying the columns of the table for which there were significant deviations between observed from random occurrences. Table 2 presents the number of simultaneous occurrences of vegetation classes given the occurrence of the class column. First, it can be seen that all of the vegetation classes across the top of the table almost always occurred more frequently in association with pine or mixed conifer types or both. Secondly, the descending order of classes related to pine and mixed conifer in Table 2 is identical to that observed in Table 1. We then considered how many vegetation classes were in association within a given quadrat.

Vegetation Type	Observed Number	Observed Percent	Random Number	Random Percent	X2 1 df	P-Value
Pine	1,405	81.4	844	74.8	17.0	0.0000
Mixed Conifer	1,037	60.0	574	50.9	22.9	0.0000
Meadow	498	28.8	281	24.9	5.1	0.0239
Aspen	432	25.0	313	27.7	2.5	0.1135
Spruce	317	18.4	204	18.1	0.02	0.8939
Spruce-Fir	275	15.9	239	21.2	12.5	0.0004
White Fir	201	11.6	82	7.3	14.1	0.0002
Locust Oak	194	11.2	87	7.7	9.1	0.0025
P.J. Savanah	173	10.0	57	5.1	22.0	0.0000
Pinyon-Juniper	93	5.4	139	12.3	43.1	0.0000
Unknown	71	4.1	54	4.8	0.6	0.4416
Douglas Fir	26	1.5	9	.8	2.26	0.1321
Barren	25	1.4	29	2.6	4.05	0.0441
Pushes	7	.4	15	1.3	6.5	0.0110
Pinyon	2	.1	1	.1	--	1.0000
Mixed Brush	0	0.0	0	0.0	--	--

TABLE 1. Comparison of frequency of use by vegetation class

Vegetation Type	Pine	Mixed Conifer	Spruce-Fir	White Fir	Locust-Oak	P.J. Savanah	Pinyon Juniper
Pine	1,405	933	203	200	188	172	92
Mixed Conifer	933	1,037	256	185	143	101	70
Meadow	449	379	156	49	1	4	3
Aspen	360	389	144	57	30	22	12
Spruce	259	284	125	18	13	2	16
Spruce-Fir	203	256	275	39	31	10	23
White Fir	200	185	39	201	59	62	0
Locust-Oak	188	143	31	59	194	81	47
P.J. Savanah	172	101	10	62	81	173	20
Pinyon-Juniper	92	70	23	0	47	20	93
Unknown	71	53	21	10	11	26	3
Douglas Fir	26	26	14	0	1	0	1
Barren	25	24	12	0	6	0	5
Pushes	7	4	3	0	1	0	1
Pinyon	2	0	0	0	2	2	0
Mixed Brush	0	0	0	0	0	0	0

TABLE 2. Frequency of observed pairwise vegetation associations

Habitat diversity, as one factor of habitat selection, was examined through tabulation of frequency of increasing number of vegetation classes within observed and randomly selected quadrats. Figure 1 demonstrates that quadrats having only a single vegetative class were avoided (P = .006) whereas quadrats containing 3 or 4 vegetation classes were selected (P = 0.014, 0.043). If we examine vegetation types most frequently associated with pine-mixed conifer, and restrict the number of classes to four, then the predominant association utilized by Kaibab mule deer was pine-mixed conifer-meadow-aspen.

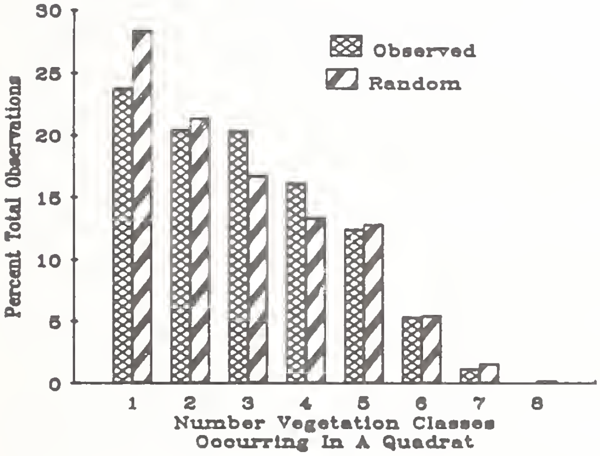

FIGURE 1. Frequency distribution of deer using quadrats of varying diversity as compared to random.

Frequency of use was found to be a function of area as well as presence. Areas of each vegetation type within quadrats were categorized into ten class intervals of .1 km_2 each. Frequency distributions were compared between random and observed occurrences using chi-square goodness of fit test. For most vegetation types, the frequencies of occurrence of deer within area class intervals decreased with increasing area class, and these frequency distributions did not vary significantly from those of random points. Area frequency distribution of pine use by deer differed significantly from that of random points and showed that deer occurred in quadrants having the greatest area of pine.

In consideration of the pine associations discussed above, we summed areas of pine, mixed conifer, meadow, and aspen for each quadrat. The resulting area Frequency distribution is presented in Figure 2, and yielded greater discrimination from random than that of pine alone. It can be seen that the zero area class was avoided and the largest area class was selected.

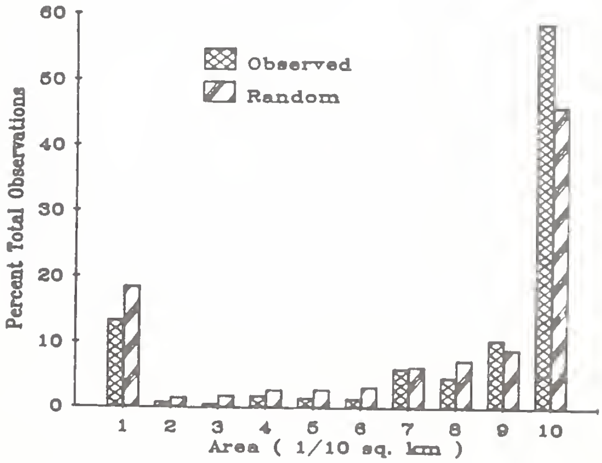

FIGURE 2. Frequency distribution of deer use by areas as compared to random, pine-mixed conifer-meadow-aspen combined.

Biological Implications

Habitat utilization of the high plateau during summer is strongly tied to associations containing pine. The emphasis must be placed on the association of pine, mixed conifer, meadow, and aspen. Vegetation diversity allows several habitat components to be present at one time. McCulloch (1982) studied Kaibab mule deer habitat utilization by relating vegetation to fecal pellet densities recorded from transects. He reported that deer were most abundant where amounts of edible aspen foliage were within reach. Hansen and Lucich (1978) examined fecal pellets of summer range Kaibab mule deer. They determined the fecal composition to be 33 percent aspen, 14 percent lupine, 13 percent white fir, and 5 percent douglas fir. Both white and douglas fir were shown by this study to be selected. Lupine is present in pine forest as a subdominant ground cover. Thermal and hiding cover is adjacent to meadows, and meadows provide access to various forbs. Therefore, a diverse habitat in a concise area is required to provide a complete diet and simultaneous cover.

This procedure provides capabilities that have not been available in past years to natural resource investigators. The ability of ARC/Info to process a large volume of detailed spatial habitat information allows the investigator to draw samples from the study area rapidly and accurately. Statistical sampling procedures can be implemented efficiently. This also includes random sampling for baseline comparison. In this study, we chose the spatial distribution of the herd as the boundary of what environment was available to the animals from which they could select primary habitat. GIS provided an automated means to set that boundary and examine use patterns within it. In wildlife research, basic questions such as where do the animals live or why there and not elsewhere, are essentially spatial in nature, and may best be investigated using GIS as a major tool.

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REMOTE SENSING AND THE GIS

Michael Lunt

ABSTRACT

Without remote sensing, the GIS effort would be totally ineffective. The planimetric base maps (Primary Series Base Maps), to which all other digitized data will be referenced, are produced by using remote sensing (aerial photographs) in conjunction with a photogrammetric stereoplotter.

The base maps are updated, usually on about a 5 to 7 year cycle, by the same process. It is only by the use of remote sensing and high-tech analytical equipment (stereoplotters) that the integrity of the mapping process is maintained. National Map Accuracy Standards (NMAS) are met by this process.

In order to capture, identify, and quantify specific resource data for the GIS effort, it is essential that we use remote sensing.

INTRODUCTION

From the author's point of view, there are approximately six major steps to the entire GIS process, viz:

1. **Capture the data** that will eventually reside in a GIS data base. Almost all of the graphical and digitized data for a GIS data base is originallly captured by some **remote sensing** method.

2. The **pertinent information** such as roads, streams, timber and soil information **is extracted** from the remote sensing source (usually photography or satellite imagery) by means of photo interpretation, digital image analysis and/or photogrammetrically digitized and/or plotted to a specific map scale and projection.

3. If not already in a digital format, the **data is digitized** and formatted for GIS.

4. **Data is entered into the GIS data base.**

5. **GIS system is queried** by the user.

6. **Graphical products** (maps) are **plotted** as well as **reports produced.**

Remote sensing is one of the key issues relative to the GIS effort and yet is currently one of most overlooked subjects. The following is a brief discussion of the remote sensing issue: What it is and its importance relative to the Forest Service GIS effort.

WHAT IS REMOTE SENSING

In the broadest sense, remote sensing is the recording of information about the earth's resources by a device that is not in contact with the resources. More commonly these devices are mounted in aircraft or satellite systems.

Remote sensing devices are instruments that measure force fields, electromagnetic energy, radiation or acoustic energy. They include cameras, lasers, radio frequency receivers, radar systems, sonar, magnetometers, seismographs, and gravimeters.

Managing the resources of the National Forests is a considerable task, but the technology of remote sensing offers a broadly consistent data base for the manager to acquire accurate resource inventories.

Paper presented at the Geographic Information Systems Awareness Seminar, Salt Lake City, UT, May 16-19, 1988.

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THE HISTORY OF REMOTE SENSING

One of the oldest remote sensing tools for recording imagery is the camera. One of the first airborn uses of the camera was by a Frenchman (Montgolfier) in his hot-air balloon, near Paris, in 1783.

The emperor Napolean III ordered reconnaissance photography in preparation for the battle of Solferino in 1859.

During World War I, the aircraft supplanted the balloons as a reconnaissance platform.

Development slowed for about 20 years during a time of relative peace in the world, and then came World War II. The development of remote sensing devices accelerated with a variety of systems and films, including RADAR systems. Multi-lense cameras, using a variety of film and filter combinations, were utilized to extract more data about the enemy's military activities, and subsequently they were used to learn more about the earth and its resources.

It was during World War II that camouflage detection film was developed. This film became available in black and white and then in color. Today this film is commonly referred to as Color Infrared.

The Forest Service has been involved in remote sensing for over 50 years. During World War II, many of the Forest Service Engineering mapping groups were converted to civilian mapping groups. These mapping groups were used by the military for mapping enemy installations and monitoring the effects of bombing missions, using aerial photography and photogrammetric mapping instruments.

For almost 30 years, Region 4 has been involved in a cyclic color photography program that provides complete Forest coverage at a scale of 1:15840 and/or 1:24000 scale. Since the 1940's, this Region has been involved in remote sensing and has been a leader nationally in photogrammetric developments and applications.

In about 1968, the Region acquired an aircraft and aerial camera for photographing various projects that were being requested as field personnel began to recognize the advantages of remote sensing and photogrammetry. Also in the 1960's, the Gemini and Apollo programs extended our use of remote sensing to the space program.

In the 1970's, Skylab and Landsat (previously called ERTS) satellites brought more precise instrumentation to the public and expanded the range of remote sensing devices. In 1974/75, Region 4 began a high altitude photography program. Today we have a national high altitude program.

In the 1980's, the Space Shuttle, Landsat, and SPOT Programs brought digital imagery to 10-meter resolution.

This Region has been active in utilizing a wide variety of remote sensing imagery including aerial photography, radar imagery, thermal infrared scanner imagery, multispectral scanners and digital satellite data.

It is impossible in this brief paper to fully explain the wide variety of remote sensing systems and their complexities; however, information about systems or applications can be obtained from the Regional Office Engineering-Geometronics Group.

Geometronics groups have been established in each Region to monitor remote sensing advancements, produce map products (hardcopy or digital) and provide advice to the field on systems and applications. These groups have, over many years, been collecting information about remote sensing and mapping and have endeavored to create high quality, accurate maps. They are a good source of information.

Almost since its inception, the Forest Service has endeavored to provide the highest quality maps utilizing the best technology available. National map accuracy standards are strictly adhered to.

It was recently revealed that the Soviets, on the other hand, have been distorting their own maps, by order of the Secret Police, to the point that their own people could not recognize their homeland on the maps.

THE HIGH QUALITY MAPS PRODUCED BY THE FOREST SERVICE FROM REMOTE SENSING DATA ARE VITAL TO THE MANAGEMENT OF THE NATIONAL FOREST LANDS. MANY OF THESE MAPS ARE USED BY THE PUBLIC, WHO VISIT THE NATIONAL FORESTS AT A RATE THAT IS 10 TIMES

GREATER THAN DISNEYLAND, WHICH RECEIVES 25 MILLION VISITORS A YEAR.

SOURCES AND APPLICATIONS OF REMOTE SENSING DATA

A variety of instruments that operate in a wide range of wavelengths are utilized by the Forest Service. The choice of instruments, operating ranges, films, filters, time of day for exposure, time of year for exposure, are determined by the anticipated end result.

Understanding, for example, that soils emit gamma radiation and water absorbs gamma radiation narrows the system choices if we are looking for the location of water bodies. If the waters that we are looking for have a different temperature than other waters in the area because of pollutants, then we may want to use a thermal scanner, which measures emitted energy (temperature). Some of these scanners are capable of resolving one-half degree temperature differences.

Knowing that bulliform cells collapse in the leaves of plants when they are stressed by wind damage, lack of water, or insect or disease infestation may require researchers and managers to use color infrared film that highlights these effects. Reflected energy from the sun reacts differently when the bulliform cells collapse in the leaves and subsequently the leaves reflect energy differently. These differences are very noticeable on infrared film.

Knowing that sick trees get a temperature, as humans do, may indicate that an instrument that measures emitted rather than reflected energy would be the most productive choice. This would mean using a thermal scanner that operates in the medium to the far infrared range of the electromagnetic spectrum. These systems can measure temperatures to within one-half degree.

Ultraviolet systems have been used to detect polar bears. Because of the ultraviolet activity in the hair of the polar bear which warms the bear, the ultraviolet image shows bears as black and the snow as white.

Radar systems emit a signal to the earth and then record how it is reflected back. Radar systems operate in the longer wavelength portion of the spectrum and, therefore, because of the long wavelengths of energy, have a sort of penetrating effect upon vegetation which reveals geological features that might otherwise be obscured by the plant life.

Figure 1, next page, displays, in a simplified manner, the major areas of the electromagnetic spectrum and the instruments that operate therein. The shorter wavelengths of energy are at the top of the chart and the longer wavelengths at the bottom.

IMAGE ANALYSIS

There are a wide variety of remote sensing systems which are detecting energy at various levels of the electromagnetic spectrum, and producing visual images for the human eye to interpret, but the human eye and brain are limited in terms of image analysis. Finding one pixel in an image that represents an element that we are interested in, and then finding all other pixels among a million pixels in a scene that have the same characteristics of the first pixel that we identified is almost an impossible task for the human eye and mind. In this kind of analysis, or in detecting changes or differences between scenes, the computer can perform in a much quicker and accurate fashion. This process is generally referred to as computer-assisted image analysis.

The Forest Service has, for many years, been interpreting information from aerial photography. Now through the use of computers, we are interpreting the imagery by two different approaches: (1) The aerial photos are scanned and converted into a digital image, and (2) satellite imagery is received directly in a digital format. The computer compares film density, reflected light, surface texture, emitted energy, etc.

The process of image interpretation usually involves restoring data cells (computing what the terrain looks like under a cloud by examining neighboring pixels), enhancing features, interpreting data electronically (pattern recognition) and quantization (digitization, coding and measuring).

ELECTROMAGNETIC SPECTRUM		REMOTE SENSING	
MINOR DIVISIONS	MAJOR DIVISIONS	INSTRUMENTS	PRODUCTS
Cosmic rays Hard Gamma rays Soft Gamma rays	Gamma rays	Gamma ray spectrom- eters. Geiger counters	Soil moisture
Hard X rays Soft X rays	X rays	X ray machine	Fractures in steel bridges Archeology
Vacuum ultraviolet Near ultraviolet	Ultraviolet rays	Scanner with Photomultipliers	Locate polar bears
	Visible light	Photo cameras Multi-spectral unit	Topography Geology Geomorphology Vegetation species
Near infrared interm infrared	Infrared	Photographic IR Film & camera	Vegetation vigor Soil-moisture relationships
Far infrared		Thermal scanner	Isothermal maps Geology Fractures controlling wtr Disturbed ground Hot springs Fire Geothermal activities
Sub millimeter Millimeter waves Centimeter waves Ultra high freq Very high freq High frequency Medium frequencies Low frequencies	Micro waves and Radio waves	Radar systems (SLAR)	Geomorphology Fractures in the earth Gross lithologies Moisture content Microwave emissivity

FIGURE 1. A sampling of remote sensing instruments and products.

REMOTE SENSING AND THE FUTURE

We are experiencing, in remote sensing, what might be termed a data explosion. Satellite imagery is becoming more available and more detailed in the data displayed.

Less than 10 years ago a typical resolution for satellite imagery was 40 meters. Currently Landsat claims 20-meter resolution, and SPOT claims 10 meter resolution. The Russians are attempting to sell imagery of the United States which is similiar to our Large Format Camera imagery. They claim 5 meter resolution. And there is talk that perhaps the United States will be forced into releasing data of higher resolution to the public.

In the meantime, the European Space Agency has launched a synthetic aperture Radar system; a Canadian Radaret system is scheduled for launch in 1990; and the Japanese, Indian Space Research Organization, and China are all planning satellite launches in the near future.

The Global Positioning system will obviously be used in conjunction with remote sensing and mapping systems to determine control coordinates and coordinates for special map features that can be easily merged with digital imagery as well as input into the GIS system.

Agreements between the Forest Service and Landsat/SPOT representatives have been signed that allow the Forest Service direct access to their raw data as well as a variety of enhanced data forms.

The emphasis on the space programs has resulted in many advances in the areas of remote sensing. The Forest Service will continue to take advantage of these developments in order to properly detect, monitor and measure the resources of National Forests.

Individuals skilled in digital mapping, remote sensing, computers, cartography and resource management will become greatly in demand.

Skilled people using the proper remote sensing techniques coupled with the GIS will make the job of managing the National Forests and its resources much, much easier.

FURTHER EXPLANATION OF SOME OF THE TERMS USED IN THIS REPORT

AERIAL PHOTOGRAPHY...The Region is involved in several programs to acquire vertical photography from low flying aircraft (1200 feet above the terrain) and high altitude aircraft (40,000 feet above the terrain). This photography is typically a 9"x9" with a natural color or infrared emulsion.

COMPUTER-ASSISTED IMAGE INTERPRETATION...The Forest Service has, for many years, been interpreting information from aerial photography. Now through the use of computers we are interpreting the imagery by two different approaches: (1) The aerial photos are scanned and converted into a digital image, and (2) satellite imagery is received in a digital format. The computer compares film density, reflected light, surface texture, etc. The process of image interpretation usually involves restoring data cells [computing what the terrain looks like under a cloud would be an example], enhancing features, interpreting data electronically (pattern recognition) and quantization (digitization, coding and measuring).

IMAGERY...This term is generally used when the emitted and/or reflected energy from a scene is not directly recorded on film; that is, when the scene is recorded by optical, electro-optical, optical mechanical or electronic means. Scenes from Landsat or Spot Satellite systems are not actual photographs and are referred to as imagery. Aerial photographs are also sometimes referred to as imagery.

OPTICAL DRUM SCANNER...This is an instrument that consists of a small drum upon which a map is mounted. The drum rotates while an optical recording device traverses the length of the rotating drum recording, pixel by pixel, the lines on the map.

PAYLOAD...In a general sense, this has reference to the instrument packages aboard a satellite system (this could include cameras, magnetometers, thermal infrared instruments, etc.).

PBS...The Forest Service version of the USGS 7.5' quad.

RADAR...An acronym that stands for **RA**dio **D**etection **A**nd **R**anging. It is an instrument that emits energy beamed to the earth, which is relected back

to a recording device, which in turn produces an image on film. It is one of many remote sensing devices.

REMOTE SENSOR...In the broadest sense, remote sensing is the recording of information about an object or feature by a device that is not in contact with the feature; i.e., from an aircraft or satellite, etc. Remote sensing devices are instruments that measure force fields, electromagnetic energy, radiation or acoustic energy. It includes such devices as cameras, lasers, radio frequency receivers, radar systems, sonar, seismographs, gravimeters, magnetometers, etc.

SCALE...Scale, in this document, is usually referred to as representative fraction; i.e., 1:24,000. These units can represent almost any units of measure. For example 1 inch=24,000 inches or 1 foot=24,000 feet or 1 meter=24,000 meters. It is usually easiest to use when thought of in units of 'inches';therefore, 1 inch on the map equals 24,000 inches on the ground. If you divide 24,000 inches by 12 you get the number of feet; hence, 1 inch on the map equals 2,000 feet on the ground.

THERMAL INFRARED...There are at least two major categories of infrared. The most familiar is the "photographic" infrared. This is a photographic infrared film that is sensitive to part of the visible portion of the spectrum and a portion of the reflective infrared portion of the spectrum. The thermal infrared, however, is sensitive to much longer wavelengths of energy and is recording emitted energy rather than reflective energy. Thermal IR deals with temperature differences.

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SPATIAL ANALYSIS FUNCTIONS USED IN MODELING GROWTH AND YIELD

Nlcholas L. Crookston and **Albert R. Stage**

ABSTRACT

Describes simulation modeling of growth and yield when pests and harvesting components are part of the model. The spatial information needed to accomplish this modeling is identified. A major thesis of this paper is that "end-users" of Geographic Information Systems (GIS's) include other systems. The implication is that a GIS should be thought of as a tool that provides final products such as maps and also as a tool that provides intermediate products useful in other systems (simulation models, expert systems, and the like).

INTRODUCTION

A major thesis of thesis paper is that people are only one of the "end-users" of Geographic Information Systems (GIS's). Other "users" are (or could be) simulation models, linear programing matrix generators and report writers, and expert systems. All of these "systems" may have uses for the spatial information and spatial analysis functions housed in a GIS without needing the front end processors of the GIS to access these data and functions. Some of the needed spatial analysis functions go beyond traditional geographic processes such as overlaying maps, allowing maps to be edited, and displaying map features and attributes. Typically, the GIS functions needed for growth and yield modeling must be executed iteratively for the entire area represented by a map, or at least, for an entire area of analysis.

Paper presented at the Intermountain Region Geographic Information Systems Awareness Seminar, Salt Lake City, UT, May 16-19, 1988.

Nicholas L. Crookston is an Operations Research Analyst and Albert R. Stage is Project Leader and Principal Mensurationist, Intermountain Research Station, Forest Service, U.S. Department of Agriculture, Moscow, ID.

To demonstrate the validity of this thesis, we describe three simulation models and two related processes that use some special spatial analysis tools. The spatial analysis tools are introduced in the context of their use. Once you have seen the applications for the tools, we hope you will agree that they are important and useful.

The three simulation models discussed are:

- Harvest simulation in the Parallel Processing Extension of the Prognosis Model.
- A multistand mountain pine beetle (MPB) model for contiguous areas.
- A MPB model that applies to a very large area.

The two related processes discussed are:

- Rotation-translation computation.
- Nearest neighbor sampling.

HARVEST SIMULATION

The harvest simulation system is housed within a multistand growth model called Parallel Processing Extension (PPE) (Crookston and Stage in preparation) of the Prognosis Model (Stage 1973; Wykoff and others 1982). The Prognosis Model is an individual-tree, distance-independent stand model, which can simulate a rich assortment of harvest and regeneration establishment prescriptions.

The harvest simulation system essentially works like this. At each time step, the model computes a target harvest using a formula entered by the user. The model also computes a priority for selecting each stand using another formula that is also entered by the user. The model sorts the stands into order of priority and selects enough stands for harvest so that the target is reached. The selected stands are

harvested according to the rules specified by the user. The process is repeated for each successive time step.

For this example, we use data from stands in part of the Nez Perce National Forest. A contiguous area of 119 stands (3,300 acres) was simulated under two harvest policies.

Policy 1:	Target	= Set the cut equal to the net growth.
	Priority	= Cut the stands that contain the most volume per acre. If stands have already been harvested, reduce the chance they will be picked again.
Policy 2:	Target	= Cut 25 percent of the total volume for each of the first three decades. Then set the harvest rate equal to the net growth rate.
	Priority	= Same as policy 1.

Details of the harvest prescription for each stand depend on the stand's aspect and habitat type. One of the following three prescriptions are carried out by the model when a stand is selected for harvest.:

- Prescription 1--Apply a shelterwood-cut, pile the slash and burn.

- Prescription 2-- Apply a clearcut and broadcast burn.

- Prescription 3--Apply a seedtree cut and broadcast burn.

All three prescriptions include the following: If natural regeneration does not provide full stocking within 10 years, mechanically prepare the site and plant. Once a stand has been harvested for the first time, perform thinnings as needed to control stand stocking.

Figures 1 through 3 show the results of running the simulation for 110 years. Figure 1 charts the number of acres treated each decade when each policy is followed. Treated acres include harvested and thinned stands. Figure 2 charts the total cubic volume removed for each policy. It is interesting to note that the second policy of early accelerated harvest followed by setting the harvest rate equal to the net growth rate results in greater yields in later decades than produced under policy 1.

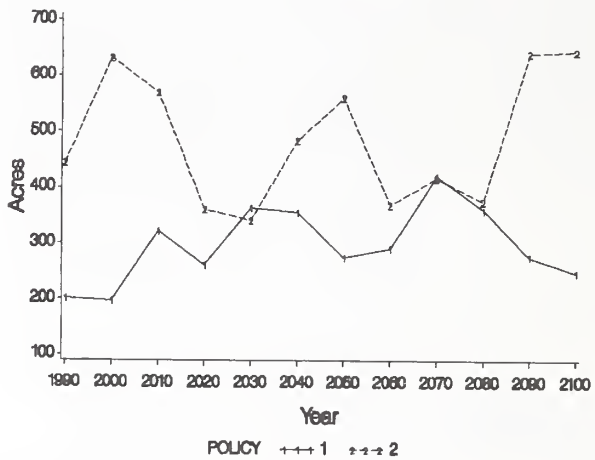

FIGURE 1. Plot of thinned and harvested area over time for each harvest policy. The areas are in acres treated in a 10-year period.

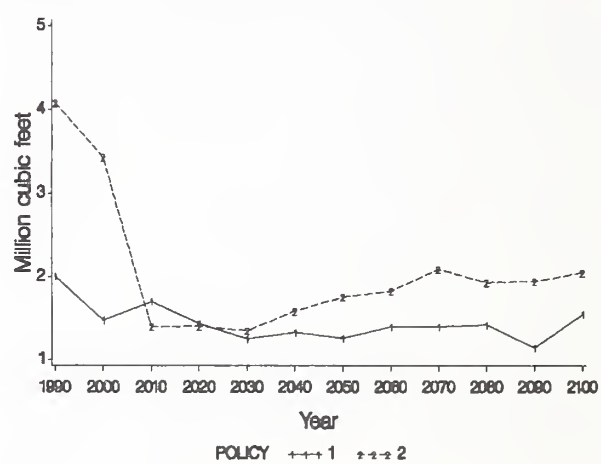

FIGURE 2. Plot of current harvest volume in millions of merchantable cubic feet in a 10 year period over time for each of the two harvest policies.

Figure 3, next page, displays maps of the analysis area that indicate which stands are harvested and which are thinned in a given decade.

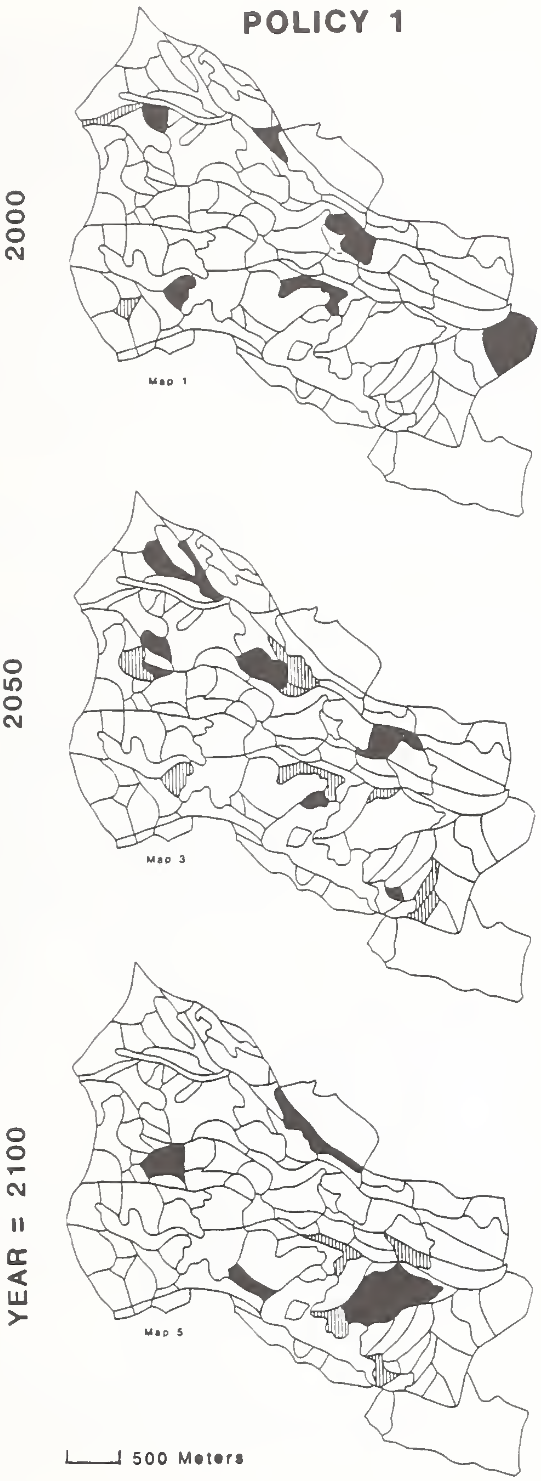

FIGURE 3. Shaded stands are thinned, solid stands are harvested. Map 1 displays treated stands under policy 1 in year 2000. Map 2 is policy 2 in 2000, map 3 is policy 1 in 2050, map 4 is policy 2 in 2050, map 5 is policy 1 in 2100, and map 6 is policy 2 in 2100.

GEOGRAPHIC FUNCTIONS RELATED TO HARVEST SIMULATION

For this analysis, all we needed from a GIS was a file listing the areas of each stand. The file also contains the location of the stand centroids. We call this file the AREALOCS file. We created the maps in Figure 3 by loading a GIS with results generated by the simulation model.

The harvest simulation system can defer stands from being harvested if the harvest would create a clearcut that is larger than a user-specified maximum. This option requires the AREALOCS file and additional data elements contained in a NEIGHBORS file. Each record in the NEIGHBORS file contains the identifications of two neighboring stands and the length of their common borders. A special GIS function is needed to create these files for use in the simulation model.

Access to roads can be used in computing the priority for harvest. This requires a file of distances from each stand to the appropriate road and is called the RDACCESS file.

Stands are not actually managed; however, they are reasonably good inventory sampling units, and they form the geographic basis for many simulation models. To make harvest simulations more relevant to planning, we need a spatial function that will convert a stand map into a map that portrays harvest unit maps. This function would presumably use a set of rules that mimic the process that timber sale foresters follow when creating harvest units.

MULTISTAND MPB MODEL FOR CONTIGUOUS AREAS

A multistand MPB model for contiguous areas is part of the PPE. This model simulates the spread and damage done by MPB's for contiguous areas of up to about 600 stands. The model uses Cole and McGregor's (1983) model to compute the rate of kill within each stand. Units of "kill pressure" (dead basal area is used as a measure of MPB population) are spread between stands using an algorithmic model. This dispersal function depends upon the distance between stands, the food supply in each stand, the length of common boundary between stands, and the amount of dead basal area in each stand.

An example of running this model is taken from an area on the Trapper Creek Quadrangle, in the Nez Perce National Forest, Idaho. Figure 4 displays three "spread" maps produced by running this model. Map 1 illustrates what happened during the second year of the outbreak, Map 2 illustrates the results for the third year, and Map 3 shows the area after 7 years of the outbreak.

FIGURE 4. Map 1 shows simulated MPB-caused damage for the second year of an outbreak as computed by the multistand MPB model for contiguous areas. Map 2 is for the third year, and map 3 is for the seventh year. Four intensities of outbreak are illustrated on each map, as follows:

	Maps 1/2*	Map 3
Dotted lines, empty polygons	0	0
Solid lines, empty polygons	0 to 10	0 to 80
Large vertical hatching	10 to 30	80 to 1,000
Horizontal hatching	30 to 80	1,000 to 3,000
Solid polygons	over 80	over 3,000

* Dead cubic volume/acre

This MPB model uses the AREALOCS and the NEIGHBORS file. The simulation model houses these data elements in memory so that it can access them quickly and efficiently. Another important feature of the data required by this model is that all of the acres in the MPB-infested area need to be included. This means that stands in private ownership need to be mapped and inventoried. The intensity of the inventory may be low (see Nearest Neighbor Sampling section), but model errors will result if private lands are represented as "lakes," or areas without trees.

AN MPB MODEL THAT APPLIES TO A VERY LARGE AREA

The contiguous-stand MPB model operates over a smaller area than MPB do. Figure 5 displays two thirds of the Trapper Creek Quadrangle. The large polygons in the upper left-hand side of the map are areas of MPB infestation as drawn on aerial sketch maps. The busy bunch of stands in the center are the same stands used in Figure 4. Obviously, significant dynamics of the MPB operate at a larger scale than the 279 stands (5,000 acres) in Figure 4.

FIGURE 5. Trapper Creek Quadrangle, ID aerial sketch map (large polygons) and stand map (small polygons). The scale of MPB outbreak is much larger than can be simulated by considering a group of 200 to 300 stands.

We need a model that operates at a Ranger District or larger scale. This model would provide a general picture of MPB populations that the contiguous-stand model could use to index overall MPB densities.

Alex Polymenopoulos and Gary Long of Washington State University did some work on building a temporal and spatial autocorrelation model that could be used to predict broad-scale MPB population dynamics. They started with a 200 x 200 meter grid sample of several quads of pest and stand data. The polygon label at each sample point was used to access data regarding stand and beetle conditions.

The resulting model is capable of capturing general current conditions and making a one-year (perhaps up to two years) projection of MPB spread over a 7.5 minute quadrangle. Their work is still in the preliminary stages and has not been published.

The special geographic function used in this work was the sampling program used to create the grid sample of many quadrangles of polygon-type maps. The program finds the label of the polygon for each of several thousand arbitrarily selected points.

FINDING ROTATION-TRANSLATION SOURCES OF ERROR

When working with models that have spatial significance, it is hard to find useful tools for objectively evaluating model performance. The problem can be stated this way: what if the MPB model predicts nearly the correct number of dead trees but does not predict the location of the outbreak very well? Comparing the predicted dead with an observed value would not reveal the error. Polymenopoulos worked on this problem as a part of the work he did on the large-scale MPB model (this work is also unpublished).

If the numbers of dead trees are correct but the location is wrong, we wish to know how much error is due to simulating bugs flying in the wrong direction and how much error is due to simulating bugs flying either too far or not far enough. For example, compare the hypothetical outbreak map displayed in Figure 6a with a hypothetical predicted map in Figure 6b. Each dot represents some fixed number of dead trees. Figures 6a and 6b contain the same

number of dots. Imagine that you can rotate the dots in Figure 6b counter clockwise and then move them slightly to the left (translation). They would almost fit over the top of the dots in Figure 6a. What Polymenopoulos did was create an analysis tool that computes the amount of rotation and translation that gives the "best" fit among two sets of grid points.

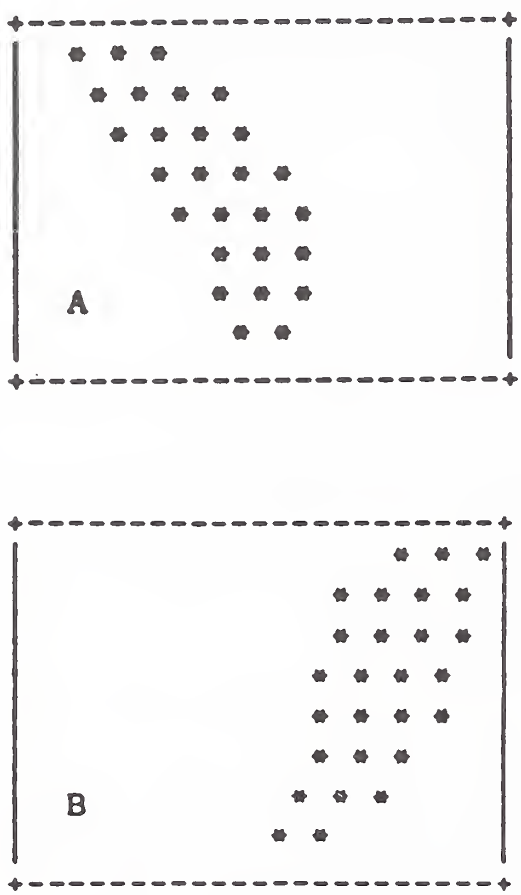

FIGURE 6. The dot pattern labeled A represents a hypothetical outbreak map and the pattern labeled B represents a hypothetical prediction that should match pattern A. The lack of match can be mostly "repaired" by rotating pattern B counter clockwise and moving (translating) it to the left.

The technique also takes into account grid points of different "size." Let's say the grid points on the bottom row of Figure 6a and on the top row of 6b each represent 10 times the number of dead trees than represented by any other points. The best fit in this case would be to move 6b down as well as to the right.

The rotation-translation system described here used the sampling program to create the data needed to compute the necessary amount of rotation and translation. In this case, the sampling program is the GIS function required to achieve the analysis goal. The rotation-translation system itself could be thought of as a GIS function in its own right, however. It would be a useful and interesting function to include in a GIS.

NEAREST NEIGHBOR SAMPLING

The PPE harvest simulation and the MPB models require a detailed inventory of each of the stands in the run. These inventories are usually not available for all stands in the area of analysis. The nearest neighbor sampling system (Moeur and Stage in preperation) is designed to provide an objective way to extrapolate ground-collected inventory data to stands for which only photo-interpreted data are available.

For each aerially inventoried stand, the procedure finds the "nearest" stand that has been ground inventoried. Nearness is measured as a composite of crown closure, habitat type, aspect, cover type, and physical location. This procedure was used on the Red River Ranger District to extrapolate inventories of about 2,200 stands to about 3,800 stands that were not inventoried. Then, the resulting "completed" stand data base formed the basis for an analysis of effects of mountain pine beetle on yields from proposed harvest areas.

The nearest neighbor procedure used the AREALOCS file to provide a measurement of physical location of stands. The remaining variables happened to be available in the timber stand data base, although they might very well be derived from a GIS.

SUMMARY

The following functions, which operate on GIS data files, were required for growth and yield modeling as well as several pest impact assessment models:

- Neighbors--creates a sequential list of neighboring polygon-type objects (stands) and the length of the common boundary between them.

- Areas and locations--creates a sequential list of polygon-type objects (stands), their sizes, and the locations of their centroids.

- Point sample program--point-samples a polygon-type map according to any arbitrary sampling distribution and returns the polygon label for each sample point.

- Road access--returns an accessibility index for each stand on a map. The geographic information for this index could be the distance a stand is from the nearest road segment, the road segment identification, and a list of road segments that tie the nearest segment to a major road.

- Convert stand maps to management maps--converts a stand map to a map more useful for portraying management units, pest spread, or both. Long and narrow stands, and stands that have multiple crescents, are divided into more regularly shaped areas.

These functions should be accessible for calling from FORTRAN and other languages. They should be capable of being executed automatically for entire maps that contain thousands of items.

Completeness of coverage is a concern in all resource modeling. The models described here base the predicted outcomes partly on the status of neighboring stands. In many cases, Forest Service stand maps show private land ownership but do not identify these lands sufficiently to infer the kind or amount of vegetation the lands support. Any models that attempt to predict migration or dispersal will require that adjoining land areas be realistically included. This need applies to the harvest and MPB models described in this paper and also applies to game migration models and watershed (flow and sediment) models. Ownership maps are best used to store ownership data in a GIS. Stand boundaries represented by a polygon map should have lines coinciding with ownership boundaries only when indicated by a discontinuity in the vegetation.

ACKNOWLEDGMENT

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SESSION 2

OBJECTIVE: To become aware of Geographic Information Systems and typical Forest applications.

Chaired by:

John Lupis, Director, Engineering, Intermountain Region, Forest Service, Ogden, Utah

George Roether, Director, Wildlife & Fisheries, Intermountain Region, Forest Service, Ogden, Utah

DIGITAL DATA STANDARDS

Dave George

ABSTRACT

With many agencies and offices of the Forest Service now faced with acquiring and using geographic data in digital form, the need to establish standards and practices regarding what sources are digitized, and what accuracy levels are attained in the process becomes pressing. Several factors affect the accuracy of digital data. Among these are: scale and composition of source material; certain cartographic practices that need to be kept in mind when digitizing maps; the nature of the Earth itself, and the various methods that are used to represent this spherical object in two dimensions; and the equipment and personnel employed in the collection process. These factors, among others, are explored here in some detail as regards their importance in the data conversion process. In addition, a short outline of the digital cartographic data collection program at the Forest Service Geometronics Service Center is presented as a model for those interested in implementing a data conversion shop, or those who may have occasion to deal with one in a contracting capacity.

INTRODUCTION

The following appeared in a letter on national GIS strategy from William L. Rice, Deputy Chief, dated February 3, 1988:

> A Geographic Information System can help improve the management of our land-based information to better meet day-to-day resource management activities. To more efficiently accomplish and monitor planned work using a GIS, the technology must be available at the Ranger District level.

It is evident from reading the above that every Forest will eventually be collecting resource data for a Geographic Information System (GIS). Some important considerations must be taken into account before embarking upon such a project. Chief among these are:

- Accuracy. How accurate are the data being collected? Will they enable the user to make the desired measurements and analyses with confidence?

- Data needs. What data are needed? Are the data being collected going to provide for the needs of all the likely users of the GIS? Is the structure of the data such that analytical processes performed on them actually yield usable information?

- Data density. How much detail is required? Are time and money being wasted by collecting too much or too little?

Of all these topics, the first, accuracy, is critical because it is the one on which the others depend. Without some assurance that the data being collected or analyzed in a GIS are accurate, any information derived would be of questionable value at best. Standards of accuracy must be established before collection begins. The most likely sources for digital input to a GIS are maps, aerial photographs and, in some cases, remotely sensed satellite data. Different types of data are assembled based on different accuracy standards. While it is not possible in a short paper to fully define all aspects of digital data standards, the basic factors that affect data accuracy can be highlighted. These are:

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- Scale

- Source

- National Map Accuracy Standards

- Cartographic Practices (simplification, generalization, symbology, feature offsetting)

- Digitizing Practices (hardware, operator accuracy)

- Stability of Base Materials

- Surveys, Photogrammetric and Geodetic Information

FACTORS AFFECTING THE ACCURACY OF DIGITAL DATA

Scale, Source, and National Map Accuracy Standards

Representing a portion of the earth's surface on a map obviously requires extreme reduction of the features portrayed. Achieving accurate placement of features can be a problem. The National Map Accuracy Standards (NMAS) require that 90 percent of all points on a map be located within 1/30-inch of their true location for maps of a scale of 1:20000 or larger and within 1/50-inch for maps of smaller scale (1:24000 for instance). If a map has a scale of 1:24000, it means that one unit of measurement on the map equals 24000 of those same units on the ground (1 inch = 24000 inches = 2000 feet). To understand the terms "larger" and "smaller" as used in reference to map scale, remember that a 1-inch line on a 1:24000 scale map would be only one-half inch in length on a map of 1:48000 scale. Thus, the 1:24000 map is of larger scale than the 1:48000 map.

The three map series in common use in the Forest Service that conform to NMAS are the Geological Survey 7.5 minute 1:24000 Topographic Series, the Forest Service Primary Base Series 7.5 minute 1:24000 maps (derived from the GS Topographic Series), and the Forest Service Secondary Base 1:126720 maps (assembled from the Primary Base maps). Ground distance, map distance, and scale factor are related like this:

Ground Distance ÷ Map Distance = Scale Factor
Ground Distance ÷ Scale Factor = Map Distance
Map Distance X Scale Factor = Ground Distance

These formulae require the inputs to be in the same units of measure. So, for a 1:24000 scale map the allowable positional error under NMAS is 40 feet on the ground; for a 1:126720 scale map, 211 feet.

Similarly, NMAS provides parameters of vertical accuracy. Ninety percent of the elevations on the map must be within one-half of the contour interval of the map. So, for a map with a contour interval of 20 feet, 90 percent of the vertical information on the map is accurate to within 10 feet of its actual elevation. A Digital Elevation Model (DEM) is a gridded set of elevation data recorded at regular intervals (metric). DEM's are probably the most widely used source of digital terrain data. The horizontal accuracy of a DEM is commensurate with the source (either aerial photography or a 1:24000 contour layer), and there are two classes of vertical accuracy: less than 7 meters (approximately 23 feet), and within 7 to 12 meters deviation from actual position. Sixty-six percent of the points in the model must meet the criteria.

All maps which state in the legend that they meet national map accuracy standards have known, quantifiable accuracy characteristics. These standards are rigorous, and it can be assumed that maps not meeting these standards are of less relative value in relating map features to actual ground truth.

Cartographic Practices

Symbolization of map features is scale dependent in some ways and not in others. Simplification, generalization, and off-setting are practices employed in map construction to enhance readability.

Simplification. The same symbol may be used to indicate a feature on maps of different scales, or some features may be symbolized differently depending on the scale of the map. Areal features on large scale maps may appear as no more than points on smaller scale maps and so on. The numerical density of features may change depending on the map scale. For example, a group of buildings on a large scale map may be represented on a small scale map by only the most prominent buildings in the group, or they may be omitted altogether.

Generalization. It is not possible to show every meander of a stream or every detail of a shoreline even on a large scale map. The cartographer must accurately portray the feature and at the same time omit unnecessary detail. The smaller the map scale, the more generalized the information becomes. There is also the concept of feature coincidence to consider. The Geological Survey Digital Line Graph Technical Notes (revised November, 1987) state:

> Coincidence may be generally defined as the condition where two or more entities occupy the same relative position. In terms of cartography, coincidence refers to the condition where symbols representing two or more features occupy the same horizontal position. This is known as symbolic coincidence.

Coincidence is a scale-dependent condition in many cases. A boundary that is shown coincident with a road on a small scale map, for example, may actually fall on one side of the road or even cross the road at different locations. This difference may be shown on a larger scale map of the area or it may not, depending on the available space in which to symbolize the feature. Another practice is to simply drop one of the coincident features, as in the case of a powerline paralleling a road alignment. The powerline does not, in most cases, stop when it nears the road, even though its symbol is discontinued. From these simple examples, it can be inferred that if a relatively high degree of accuracy is required, a larger scale map might be a better source document than a small scale one.

Off-Setting and Symbology. If a trail is symbolized using a .005-inch line (a common line width used on both Primary and Secondary Base maps), this line, strictly interpreted, represents a trail width on the ground at 1:24000 scale of around 10 feet (possible); while on a 1:126720 map this .005-inch line represents around 53 feet (possible, but not likely). If several features must be shown in a small area, putting them in their true location on the map would place them on top of each other. A cartographer will off-set the features (move them apart) to improve the legibility of the map. A good example of this is a road, railroad, and a river all running parallel through a narrow valley. Their combined width on the ground may be around 100 feet. If each feature is drawn on the map using a line width of .005-inch, with the same distance between each line, an area .025-inch wide is needed. The smallest scale at which this could be accomplished without off-setting the features is 1:48000. This conflict may occur at any map scale, and varying degrees of positional error can result.

Digitizing Practices

Input of map and aerial photograph data to a GIS requires digitizing. Accuracy in digitizing is affected by both the hardware and the person using the hardware. Digitizers (hardware) are rated by accuracy, or their ability to faithfully record input. Digitizer accuracy has two facets: resolution and repeatability. The resolution of a digitizer is the smallest increment of distance that can be registered and recorded, while repeatability is the ability to revisit the same point more than once within a prescribed margin of error. In practice, if a digitizer has a resolution of .001-inch, but a repeatability of only .01-inch, the best accuracy that can be expected at a map scale of 1:24000 is 20 feet; at 1:126720 around 105 feet; and no better than 67 feet on a 1:80000 aerial photograph.

A wild-card is thrown into the equation when we add the operator. Whether the operator follows the center of the line, or one edge of it, or follows it at all can affect the accuracy of what is entered into the computer. Generalization can be increased if the operator doesn't closely follow the alignment of the feature being collected. To demonstrate, consider this example: The operator is collecting polygon data from 1:24000 scale aerial photography. The polygons have been drawn with a rather wide pen (one-tenth inch or 200 feet on the ground). For the sake of simplicity, let's say the operator is currently digitizing a circular polygon with a radius of 1000 feet and an area of approximately 72 acres. Should the operator decide to follow the line at its outer edge, that same polygon is recorded as having a radius of 1200 feet and an area of approximately 104 acres.

Stability of Base Materials

Mylar and photographic film are considered to be stable base materials; that is, they hold their shape and size in varying conditions of temperature and humidity. Paper, on the other hand, is not a stable base material. A map or aerial photograph printed on paper can vary in size by as much as one

percent, owing to the factors mentioned above. Folding and crinkling the paper adds to the problem. One percent may not sound like much, but consider that on a 1:24000 scale paper map with a north-south dimension of 24 inches, a one percent shrinkage represents around one-fourth inch or 480 ground feet.

Surveys, Photogrammetric, and Geodetic Information

Although inaccuracy is inherent in every data source, aerial photography presents special problems. Quality and accuracy of aerial photos can be affected by atmospheric conditions, the equipment used to obtain the photos, the curvature of the earth, and other factors. On the same aerial photo, the scale varies depending on the elevation above datum (except for orthophotos). For a photo taken at an altitude of 40000 feet above datum, using a focal length of 6 inches, the scale of all points at datum is 40000 divided by .5, or 1:80000. For a point 1000 feet above datum, the scale changes to 39000 divided by .5, or 1:78000. This difference will affect the accuracy of measurements taken or features digitized. Another problem is vertical displacement. Elevations on stereo pairs of aerial photos appear exaggerated. The rougher the terrain, the more noticeable the problem. Straight features can appear to be crooked, and will be digitized as such.

Forest Service cadastral surveys are required to be accurate to no worse than one part in 5000, while engineering surveys vary from one in 1500 to one in 30. So, along a distance of 5 miles, starting at a point known to be correct, the end point reached may be in error by from 5 to 880 feet, depending on the survey method. To obtain reliable information from digitized cadastral or engineering data, it is necessary to know the level of accuracy of the survey used.

The science of geodesy deals with accurately measuring the shape of the Earth. There is no distortion-free way to portray a spherical object on a flat surface such as a map. In fact, the Earth is not a perfect sphere, but an irregular spheroidal object. Various reference spheroids (referred to as geoids) have been developed to represent parts of the Earth's surface. In the U.S., the North American Datum of 1927 was used until recently. All maps and surveys made since then are relative to this datum. With the advent of satellites, a more accurate datum, NAD 83, has been defined. Coordinate systems have been adjusted accordingly. Unfortunately, the correlation between coordinates from the NAD 27 datum and the NAD 83 datum for the same location can vary widely. This becomes important when attempting to incorporate satellite data into a GIS or when using satellite bearings from the Global Positioning System. All coordinates obtained from GPS are based on NAD 83 and will probably need to be converted to NAD 27 to match other data sources.

To locate a position on the ground, or on a map, a coordinate system must be used. When digital data are collected, they no longer have a scale within the data base, but are referenced by a coordinate system. A coordinate system must have an origin from which measurements originate and a unit of measure. One system that is consistent over the entire Earth is the Geographic (longitude-latitude) coordinate system. The Earth is divided up into 360 degrees longitudinally and 90 degrees above and below the equator latitudinally. The problem of projecting an entire spherical shape onto a flat surface makes this system too inaccurate for mapping. Other systems, most commonly State Plane (feet) and Universal Transverse Mercator (meters), minimize the distortion by dividing the surface into zones. So, instead of trying to flatten out an entire sphere, smaller rectangles (zones) from the surface are used, thereby limiting distortion to workable levels. The zone within which the data fall (or an adjacent one that does not produce negative coordinates if the area collected is large) should be the basis of the coordinates used when collecting digital data. This way more accurate positioning is achieved regardless of the coordinate system chosen.

Additional Considerations

When integrating data from different sources into one data set, difficulties arise. The consistency of adjacent, coincident, or even identical features from two sources will vary. Two adjacent maps of the same scale, even within the same mapping series, can have edge matching errors. Trying to solve the problem of differing scales by photographic means (enlargement or reduction) never yields satisfactory results; the accuracy level is still the same even if the map or photo is on a bigger or smaller piece of paper. Simplification and generalization problems

will remain, and the orthogonality of the map may be distorted during the process.

DIGITAL COLLECTION AT THE GEOMETRONICS SERVICE CENTER

Collection of digital planimetric and terrain data is under way at the Forest Service Geometronics Center. Primary Base Series 1:24000 scale maps and NHAP aerial photography are the sources used. Primary Base Quadrangles, Secondary Base Maps and Digital Elevation Models are produced from the data in support of the center's production goals. All drafting (except the placement of map lettering) for projects produced by the Automated Cartography (AC) group at the center is performed by automated means.

Hydrology, transportation, boundaries, landnet, land status, culture, and topography data are collected. Elements in planimetric files are named using three digit codes that, for the most part, parallel those used by the Geological Survey on its 7.5 minute Topographic Series Maps. X, Y, and for terrain files, Z coordinates are recorded for each point on the file. The files are converted to Geographic coordinates before plotting so that the quadrangle may be projected in any of several available map projections supported by the Forest Service Plotting System (FSPS) software.

Further processing may be performed if the intended use of the data is for input to a GIS. Points may be added to identify centroids of open water and status polygons; polygon and intersection closure is checked and adjusted, and the component elements of the file can be separated into subsets based on themes requested by the user. The files are then converted to a format that is readily usable on the Data General system for shipment.

The center's Cartographic Data Edit System (CDES) provides interactive edit and data verification capabilities for digital planimetric data, which are obtained from outside contracting efforts. Contract specifications call for data to be within .003-inch (6 feet) of their actual position on the map at 1:24000 scale. Digital data files are plotted, using the FSPS software, and checked against the source base for compliance. Other parameters checked include the attributes (names) of elements in the file, accuracy and construction of element intersections, and the integrity of known ground control points (through a root mean square error calculation) as they exist in the file.

Digital elevation models are constructed using data from the Line-Trace system or photogrammetric equipment. For the Line-Trace, 1:24000 contour layers are recorded by an optical scanner and input in raster format. The data are then vectorized and tagged with elevation information. Points from NHAP aerial photography are collected on a three axis stereoplotter at regular intervals in the photogrammetric method. The data are gridded and formatted using the General Terrain Manipulation System (GTMS) software. Once the DEM is constructed, the Interactive Data Edit System (IDES) is used to review it and make minor changes as needed.

The Line-Trace system is also used for processing polygons. The data are input by scanning, and the polygons are attributed and vectorized. At present, the system only produces output in the Resource Information Display System (RIDS) data exchange format. The Washington Office development group is currently at work expanding the number of data output formats on the system.

CONCLUSION

A Geographic Information System is only as accurate as the **least** accurate data it contains. While no specific digital collection method is right for all situations, there are some basic concepts that should always be kept in mind. Adequate data accuracy protocols should be established before the data are collected; the intended uses should be known in advance. This lessens the likelihood of collecting data that are inappropriate for the situation in which they will be used and saves both time and money.

USE OF GEOGRAPHIC INFORMATION SYSTEM TECHNOLOGY ON THE SIUSLAW NATIONAL FOREST

John R. Steffenson

ABSTRACT

As one of several Forests participating in the agency's Controlled Evaluation of Geographic Information System (GIS) technology, the Siuslaw National Forest installed ARC/INFO software in July 1987 and has subsequently automated basic resource layers and implemented a number of applications. In 1986, the Siuslaw used the Map Overlay and Statistical System (MOSS), a public domain GIS software package, to design and implement a Vegetation Resource Inventory. This paper briefly describes several GIS applications in the Siuslaw National Forest.

INTRODUCTION

The Siuslaw National Forest has been involved with Geographic Information System (GIS) technology since early in 1984 when the Forest Service contracted with Tomlinson Associates, Inc. to conduct workload analyses on six Forests throughout the country. Since then, the Siuslaw has used both Map Overlay and Statistical System (MOSS) (in support of a Vegetation Resource Inventory in 1986-7) and ARC/INFO, since July 1987 (in support of the Forest Service Controlled Evaluation of GIS technology). Through these and other GIS applications, the Siuslaw has gained a fair amount of experience in preparing for and in the actual implementation of a GIS in support of a variety of natural resource applications. By sharing our experiences, and those of others, it is hoped that many costly and time-consuming mistakes can be avoided. Further, only through the exchange of ideas and experiences may the full potential of this technology be realized.

Paper presented at the Geographic Information Systems Awareness Seminar, Salt Lake City, Utah, May 16-19, 1988.

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VEGETATION RESOURCE INVENTORY

The National Forest Management Act (NFMA) of 1976, requires that the Secretary of Agriculture maintain a current inventory of all renewable resources under its jurisdiction (Sec. 6; National Forest Management Act of 1976, 16 U.S.C. 1600[note]). The principal reason for this, is in support of Forest planning and regional and national information needs. Each Region within the Forest Service maintains an inventory program in support of this mandate. In 1982, Region 6 (Oregon and Washington) suspended all inventory work in order to evaluate and re-design the inventory process because of concerns regarding how well the program was meeting Forest planning needs. After nearly two years of effort, a new, integrated approach to resource inventories was implemented consisting of three sampling protocols:

1. VRS, Vegetation Resource Survey, for natural stands.

2. MSS, Managed Stand Survey, for managed stands.

3. MO/MS, Mature and Over-Mature Survey, for older Forest stands aimed specifically at building an information base from which to answer questions regarding the quantity and quality of "old-growth" conditions on NFS (National Forest System) lands in Region 6.

In 1984, about the same time the Forest Service was conducting the workload analysis, the Siuslaw made a proposal to the Region 6 GIS Steering Committee to install and implement the MOSS software package in support of a Forest-wide Vegetation Resource Inventory. Because the Forest was already well over-due for an inventory, and the

Controlled Evaluation of the national GIS implementation was still in the planning phase, this proposal was accepted and the Siuslaw began data collection and field mapping.

Methodology

This project consisted of first developing two photo interpreted map layers depicting different vegetative conditions. One map, of existing Forest stand conditions, included attributes for major and minor tree species, size class and density. Managed stands also received attributes for stocking, age, and stocking quality. The second photo interpreted map layer was one of grouped plant associations, which are, "a kind of plant community of definite composition, presenting a uniform physiognomy and growing in uniform habitat conditions", (Daubenmire, 1968). Groups of plant associations, as defined in the Plant Association and Management Guide, Siuslaw National Forest (Hemstrom and Logan, 1984) are indicative of, at least, site productivity range, silvicultural treatment opportunities and various wildlife considerations. They are an important management tool on the Siuslaw and, it was felt, that combined with stand condition information, we would be able to adequately define the range of vegetative conditions on the Forest.

Stand conditions and plant associations were field mapped on separate mylar overlays (single matte, opaque mylar) registered to nine inch by nine inch, 1984, 1:12,000 color aerial photos. Field checked delineations were then manually transferred (utilizing mirrored stereoscopes) to 1:12,000 black and white Resource Orthoquads (ROQ's, Region 6's orthophoto map base consisting of 7 1/2' by 3 3/4' orthophotos printed at either 1:12,000 or 1:15,840). Finalized map layers consisted of half matte, opaque mylar (registered to individual ROQ's) with either stand or plant association delineations carefully drafted with film drafting lead (plastic lead) and attribute codes placed inside the corresponding feature polygon in non-photo blue pencil.

Completed and checked map overlays were then sent to the Forest Service Geometronics Service Center (GSC) in Salt Lake City, Utah for optical scanning. Map layers sent to GSC for scanning were first photographically reduced (to fit the ten inch by ten inch format of the scanner drum) using contrast enhancing techniques (to compensate for having used film lead instead of ink). The reproduced map layer was then mounted and scanned using the Center's P-1000 Optronics Drum Scanner. Scan images were then checked for quality and then transferred to the Center's Data General mini-computer for electronic retrieval by the Siuslaw.

These digital scan files were, once retrieved, downloaded to a Hewlett-Packard 9020 IGS (Interactive Graphics System) workstation (LOT 7 procurement) for editing. A Forest Service digitizing and editing program know as LIDES (Local Interactive Digitizing and Editing System) was utilized to edit the scan images, input attribute codes and to format the map files for use in the MOSS software environment. After the map layers were digitized, attributed, and reformatted they were then uploaded, back to the Siuslaw's MV-10000 Data General mini-computer. MOSS was then utilized to overlay the Stand Condition and Plant Association layers with the resulting map defining the range of vegetative conditions existing on the Siuslaw. This stratification is comprised of nearly 15,000 unique conditions though, many do no exist, are very limited in extent, or do not reflect a meaningful condition in terms of management.

Because it is not feasible to sample a stratification even half the size, MOSS and DG PRESENT were utilized to aggregate this stratification, or matrix of conditions, into one which was meaningful (in terms of growth, yield, management implications, wildlife, etc.), and is identifiable on the ground. To that end, several interdisciplinary meetings were held to collapse this matrix into one that met those objectives. Each meeting brought an corresponding reduction in the size of this matrix. Graphic and tabular listings of this matrix were produced at each phase of this process using extracted attribute and acreage data from the GIS data base. The final stratification consisted of 62 strata representing the range of natural, or currently un-managed stands, and 120 strata defining the range for managed stands.

Both the VRS and MSS projects have been completed and field samples have been collected. During the fall/winter of 1987, data collected for use in the MOSS environment was converted to be useable in the ARC/INFO environment. Plot data will be analyzed and later linked to the digital map information as strata averages and, perhaps, some site specific information as well. The final product is envisioned as map and tabular data of sufficient

detail to satisfy both Forest planning needs as well as a range of project-level applications.

Currently, the maps are being used in support of the first phase of the Mature and Over-Mature Survey. Currently, a contractor is developing a data base of additional attributes for all natural stands on the Siuslaw utilizing photo interpretation techniques and field verification. There are number of attributes being sought, but the majority attempt to describe the vertical diversity of a given stand in terms of species composition, size, percent cover, etc. by canopy layer. Combined with existing stand information, we hope to be able to describe the range, and subsequently develop the stratification, of vegetative and structural conditions existing in mature and over-mature stands on the Siuslaw. Field verification will occur next year with the resulting data and maps being incorporated into the information base being developed. When completed, this project will have produced a data base capable of producing maps and information in support of a variety of applications concerned with conditions found in mature and over-mature stands on the Siuslaw.

Hopefully, this approach will meet not only Forest level planning needs but will form the basis for a single, comprehensive, and integrated data base of basic vegetative data usable and accessible by a variety of resource specialists for all levels of resource information needs. One long term goal of this philosophy is to explore the possibility of incorporating comparable growth and yield information such as stand exams, ecology plots, reforestation surveys, etc. in order to be able to view all or part of the available information regarding growth and yield from a single environment. Further, relationships between various resources may be readily explored utilizing the tools provided with the advent of GIS.

NATIONAL GIS STRATEGY

As mentioned previously, the Siuslaw is one of the Forests participating in the Controlled Evaluation of GIS technology. This is one part of a three phase strategy for incorporating the technology into the Forest Service. In 1984, the Forest Service hired a consultant (Tomlinson Associates, Inc.) to perform Workload Analyses on six Forests. This process attempts to identify most of the desired products to be derived from a GIS and the data layers required to support them. The document produced from that effort identified more products and layers than will probably ever be realized but served well as a starting point. Later the Forest re-worked that document to be realistic in terms of budget, personnel, timelines, etc. Products and layer development were prioritized while, allowing for flexibility in anticipation of changing priorities.

The second phase, consists of the Controlled Evaluation which is approximately one year into the two years allowed for it. This phase has involved the installation of GIS software (ARC/INFO or MOSS at this time), training and implementation of basic digital information. As part of that effort, the Siuslaw has identified 12 layers of information to be automated and two products to produced. The first product to be completed will be an automated version of our, currently manual, sale scheduling process. This product is currently being developed and anomalies between districts is being built into these. Once specialists become familiar with the GIS process for doing this, it is hoped that standardized processes may be developed.

The third and final phase of this strategy is the actual procurement of the actual agency-wide software and is currently scheduled for late 1990 or early 1991. Preparations for this procurement have already begun, with the Washington Office utilizing field personnel to provide expertise and labor for this effort. Of all the valuable learning experiences offered by participating in the early effort, the workload analysis, in particular, was of immeasurable benefit in having a successful installation.

The Siuslaw, also as part of the Controlled Evaluation, has, and continues to, perform a variety testing and evaluation work related to hardware configurations, system impacts, remote access, cost/benefit documentation, etc. The Forest recently tested a Data General Workstation for the Controlled Evaluation and hopes to implement this or similar technology for use at field offices, since currently the Districts can only utilize the software on the Supervisor's Office system via telecommunications.

OREGON DUNES NATIONAL RECREATION AREA INVENTORY PROJECT

The Siuslaw is responsible for, among other things, management of the Oregon Dunes National Recreation Area (ODNRA) located in a narrow strip along the coast and extending some 40 miles along the southern half of the Forest. This 30,000 acre NRA is comprised of a dune ecosystem characterized by large, moving or "living" dunes intermingled with stabilized dunes (vegetated), salt marshes and Forest islands contained within the open sand areas. Currently, the ODNRA is managed primarily for recreation, wildlife habitat, fisheries, unique scenery and the like.

Starting in the 1950's, the Oregon Highway Division and others introduced a European variety of beach grass in an effort to stabilize dunes threatening public roadways. While other plants were also introduced, this species has proven to be so vigorous that specialist are now concerned with the future of the open, moving dune formations. A long narrow ridge of stabilized dune has now formed, just beyond reach of high tide, for nearly the entire length of the ODNRA, effectively cutting off the supply of fresh sand carried inland from the beach by the seasonally strong winds.

In 1972, a group of specialists completed an inventory and mapping project which defined and mapped approximately 30 geomorphic / vegetative features found on the ODNRA. In 1987, in cooperation with the Area Ecologist, the Siuslaw undertook a new classification and mapping project designed to answer questions regarding the status and future of vegetative and landform conditions found on the ODNRA. There are several objectives of this project. The first is to refine and/or validate the 1972 inventory, adding community descriptions as indicated by evolving conditions on the dunes. This is being accomplished through the installation of many ecological reconaissance plots and through the installation and long-term monitoring of vegetation transects being installed at this time.

The second objective is to quantify both the short- and long-term changes in vegetation and landform being observed by specialists on the ODNRA. To accomplish this, a special photo series was flown in during early summer of 1987, and the refined classification schema was field mapped and checked. Field delineations were transferred to orthophoto overlays, and at this time they are in the process of being optically scanned and digitized. Once the 1987 data has been digitized, a similar process will be used to automate the features delineated in the 1972 effort on the same orthophoto base as the 1987 data. By comparing the two layers, we should be able to address, with specifics, any number of question regarding the events and trends related to vegetation and landform changes and the interaction of the two. Again, as with the other inventory projects on the Siuslaw, the emphasis is on developing basic resource information at a resolution sufficient to meet all project and program level needs.

TRAIL LOCATION MODELING

Related to the other GIS work on the Oregon Dunes is a cooperative project between the Forest and a graduate student involving the development of a model to assist in location of a trail. The Region 6 Geometronics group is currently developing a Digital Elevation Model (DEM - digital file containing many {x,y,z} coordinate elevation values). DEM's are intermediate products generated in the process of making orthophotos and are themselves used to generate contour maps, perspective plots, and the like, with a resolution of one to two meters. This will allow the accurate production of layers such as slope, aspect, contour, perspective and other terrain models.

Such other themes of resource information as visuals, wildlife habitat, vegetation (from the inventory project), and streams have been or will be developed for the same area. Relative values will be assigned to various features in each layer depending on their particular value in relation to the development of a recreational trail. Next, an octagonal grid will be generated with polygons of a small enough size to be useful in the actual placement. Resource layers will be individually overlaid in the GIS and the weighted values already assigned will be copied into a file associated with each node, or intersection on the grid. When the table is complete, various combinations of values can be associated to the nodes on the grid as impedance values. A network program associated with the GIS can then determine the path of least resistance, based on any number and combination of resource values.

STREAM REACH MAPPING AND RIPARIAN MODELING PROJECT

The Area Ecologist is also involved with network analysis as it applies to stream reaches and riparian ecosystems. Geomorphic stream reaches were mapped for three sample watersheds on the Forest by the Ecologist last year. A variety of data was collected for each reach as attributes related to features such as channel width, valley width, geology, pool/riffle ratio, relative percent of different size sediments, large woody debris, etc. Other layers can be associated with the network of stream reaches, allowing specialists to explore relationships between basic resource components as part of large, complex systems.

There are many applications for these kinds of projects on the Siuslaw and a variety of products are currently being developed and evaluated by the Area Ecologist. For example, modeling of the interaction between stream reach attributes, riparian vegetation and the like, in relation to fisheries, will be of immense value in managing the miles of anadromous fish habitat on the Siuslaw. It will also help in the monitoring and modeling of the effects of management activities on streams and fisheries. Upon conclusion of these initial tests, development of Forest-wide stream reach maps and applications will follow.

SUMMARY AND CONCLUSIONS

In summary, while this is not a complete list and description of the GIS activities on the Siuslaw, it does briefly cover many of the major efforts to date. We have only begun to realize the benefit of this technology on the Siuslaw. As we continue to develop map information and utilize the tools provided by the GIS software, I believe we will realize an acceleration in the benefits and, perhaps, an increase in the value of some of the applications.

A great deal of effort is required to implement any GIS. The success of each installation is directly related to the quality of preparation and depth of understanding by key personnel of the data and information needs of the resource specialists for whose area a particular installation is designed. It is important to remember that it is easier and cheaper to produce meaningful products from a data base which was carefully designed and checked before being automated than it is to try and develop products from a data base without design or one full of errors. Resource specialists themselves need to familiarize themselves with the basic concepts and requirements for accurate processing of information in a GIS environment, for they are the individuals who will ultimately derive the highest benefit within the agency.

Finally, I see a great deal of promise in the technology and in the strategy the agency has employed. I think it will be almost required, at least in some circumstances, for maintaining the quality, diversity and intensity of management and use of a variety of resources in the National Forest System. We are far from a complete understanding of the complex interactions of various resources and our impact on them. GIS will go a long way toward improving both our understanding of those interactions and in monitoring the effects of our activities.

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THE TONGASS NATIONAL FOREST GEOGRAPHIC INFORMATION SYSTEM (GIS) EXPERIENCE

Martin L. Prather

ABSTRACT

The Tongass National Forest three-year involvement with Geographic Information Systems includes a data management study and three years of GIS use in Area Analysis and Forest Planning. GIS has improved time distribution, and facilitated communication, interdisciplinary interactions, planning alternatives, cumulative effects analyses, NEPA documents, and plan implementation. Additional benefits from full GIS implementation should include significant time and dollar savings, improvements in accomplishment reporting and tracking, increased data sharing, and reduced data redundancies and losses. Suggested steps for successful GIS implementation include implementation planning, guiding the software industry, ensuring awareness of change, early training and recruiting of skilled employees, and conducting a pilot project.

BRIEF HISTORY

The Tongass National Forest (NF) began investigating Geographic Information Systems (GIS) in 1982 when Forest managers recognized a need for better management of natural resource information. Subsequent activities led to the Natural Resource Management Information Study (NRMIS) contracted to Environmental Systems Research Institute in February, 1984 (Environmental Systems Research Institute, 1984 a & b, 1985).

Paper presented at the Geographic Information Systems Awareness Seminar, Intermountain Region, USDA Forest Service, Salt Lake City, UT, May 16-19, 1988.

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This study consisted of four phases:

1. Data and User Assessment -- The contractor interviewed Tongass NF personnel from all disciplines and organizational levels to determine data and geographic analysis needs.

2. Preliminary Database and System Design -- Based upon the results of Phase 1, the contractor recommended a database structure, system design, and software.

3. Pilot Project -- The proposed database and system were tested on the Cleveland Peninsula Area Analysis by developing a database for the 200,000+ acres included in the planning area and conducting all analyses for the planning process. The contractor used the proprietary software, ARC/INFO, for this pilot project.

4. Final Design and Implementation Plan -- Improvements that surfaced during the pilot were incorporated into the database and system design. The contractor proposed a final Tongass-wide system and implementation plan.

At the completion of the study in April 1985, the Tongass NF arranged to lease the ARC/INFO software to finish the Cleveland Peninsula Area Analysis with the pilot database. The software was installed, ten interdisciplinary (ID) team members received software training, and Tongass personnel first began using the GIS software in February 1986.

In April 1986, the Region 10 Regional Forester formed a GIS Task Force to assess alternatives for implementing GIS throughout the Region. Nine alternatives were eventually examined (USDA Forest Service, 1986a). The Regional Forester chose one for implementation in June 1986 and directed the Task Force to prepare the documents needed to solicit Washington Office (WO) and US Department of Agriculture (USDA) procurement

approval. This package (USDA Forest Service, 1986b) was completed in September 1986.

In January 1987, the WO included the Tongass NF in the National Controlled Evaluation of GIS and authorized the purchase of four sets of ARC/INFO software and the associated workstations. The Tongass NF subsequently decided to evaluate the GIS software through preparation of the Tongass Forest Plan. Development of the Forest Plan GIS database began in August 1987.

CURRENT STATUS

The Tongass has used the GIS primarily to support planning processes. These projects and their current status are as follows:

- The Cleveland Peninsula Area Analysis (250,000 acres). Completed.

- The 1989-1994 Operating Plan for the Ketchikan Pulp Company 50 Year Timber Sale (1 million acres). EIS drafted.

- The Revilla Island Area Analysis (500,000 acres). Draft EIS in preparation.

- Tongass Forest Plan (16 million acres). Database 50 percent completed.

DEMONSTRATED UTILITY

In Planning

Several benefits of GIS facilitated planning have surfaced during the Tongass' use of the ARC/INFO software. These benefits are described in the following paragraphs. GIS/non-GIS comparisons are unquantified impressions of ID team members and managers experienced in both methods of planning. Data that should confirm these impressions are now being collected through the Controlled Evaluation.

Improved Time Distribution. The data manipulation aspect of Plan development can be divided into two general phases -- database preparation and data analysis. database preparation occurs early in the planning process, and data analysis is associated primarily with alternative development and cumulative effects analysis. Under non-GIS methods, analyses require considerably more professional employee time than database preparation. In contrast, GIS database preparation is time consuming while analyses are processed rapidly. Interdisciplinary planning team members found that this redistribution of effort to early in the planning period allowed more time for creativity, coordination, interdisciplinary interaction and public involvement during alternative formulation and cumulative effects analysis.

Time Savings. Until ID team members became somewhat proficient with the GIS software, the rate of plan development was similar to non-GIS planning. Planning progressed faster as software proficiency increased, leading Tongass users to expect considerable time savings from future GIS facilitated planning.

Citizen Participation and Scoping. Communication with publics improved considerably when Plans were developed with a GIS. Colorful, neat, accurate maps were generated rapidly. This allowed teams to easily tailor maps to different audiences. Ideas for alternatives generated in open houses and public meetings were more easily captured and displayed with a GIS database, demonstrating our attention to public concerns.

Under non-GIS processes, map preparation consumed so much time that teams often were forced to use maps hastily prepared by hand and to sacrifice detail, accuracy, and professional appearance. Communication effectiveness declined because maps intended for one audience were used for many audiences.

Alternative Formulation. Interdisciplinary teams found that greater numbers of management options could be explored when developing plans with a GIS. Resulting alternatives better addressed planning issues and were more implementable. Greater numbers of alternatives could be effectively evaluated, and teams could more easily evaluate selected alternatives composed of portions of several alternatives.

The GIS elevated interdisciplinary interactions between team members by providing an easily accessible source of all resource data and by allowing a quick display and evaluation of overlapping resource values. Non-GIS processes

discourage testing of new ideas and options because of the time required to generate new maps and to evaluate data. Feedback was rapid with the GIS system. Ideas proposed in a planning meeting one day were processed in batch runs that night, and new maps and tabular information were waiting for the ID team to evaluate the next day.

Cumulative Effects Analysis. The GIS opened many analytical doors by making techniques practical for routine use, that although previously available, were too time consuming. For example, four data-intensive models proved valuable when a GIS generated and organized the data necessary to fuel the models -- a Sitka Black-tailed deer cumulative effects model, a stand growth simulator, a transportation planning model, and a scheme for subdividing the landscape into wildlife habitats. These sophisticated tools improved the credibility of the effects analyses and resulting decisions with several concerned citizen and professional groups.

Document Preparation. Without a GIS, skilled cartographers prepare maps for printing by manually creating map layers for each desired color plate. This time-consuming step tended to delay NEPA document completion. Tongass teams avoided this by producing color plates directly from map layers plotted with the GIS software.

NEPA document data tables were created directly by the GIS system. Teams are now loading data files into Data General (DG) data tables and then using DG graphics to produce charts. Other graphics software packages can be directly linked with GIS software to generate attractive graphs and charts from the GIS database. This direct link with the GIS database will eliminate transferring data to other graphics software packages.

Plan Appeals. Since responding to Forest Plan appeals often requires extensive data reorganization, calculation, and display (maps and tables), GIS capabilities in these areas will facilitate a more rapid response to appeals.

Implementation. Tongass teams expect GIS to be useful during plan implementation in two ways. The database and electronic products (maps and data tables) are reliable tracks of the planning process and resulting decision and are accessible to all disciplines. In addition, the database can be easily updated and refreshed as implementation proceeds, creating a detailed progress record. Without reliable tracking processes, implementation tends to stray from that intended by the planning teams.

Other Expected Benefits

Tongass users of the GIS expect many benefits from full GIS implementation in addition to those realized in planning projects.

Time Savings. The GIS Task Force estimated likely time savings from using the GIS for all applicable tasks in the Region over 10 years (USDA Forest Service, 1986b). These savings were translated into dollars and used in a benefit/cost evaluation showing a 2.5 benefit/cost ratio. Clearly the time savings could be redistributed to other important tasks if additional work were considered a priority over fiscal savings.

Improved Accomplishment Reporting and Tracking. The ease of updating the spatial components of the GIS database would markedly improve our ability to track accomplishments and reference them to a physical location. That information could then be easily summarized, electronically transferred to other organizational levels, and merged with similar information from other units.

Data Centralization and Integration. Resource data is currently scattered throughout a variety of different types of electronic databases, hand or electronic mapping systems, and manual filing systems. Data management is inconsistent and inefficient and often leads to data gaps, overlaps, and losses. These current methods of data management and retrieval do not accommodate the needed levels of data sharing and interchange.

A GIS would serve as a unit's central location for the storage, access, and update of information for all resource disciplines and as a focus for database standardization and integration. These qualities facilitate data sharing, true interdisciplinary interactions, and reduce redundancies and data loss.

BLUEPRINT FOR SUCCESSFUL IMPLEMENTATION

The implementation of a GIS system generated many challenges for managers, resource professionals, and other personnel on the Tongass. The following steps are suggested to help ensure a smooth implementation of GIS by our workforce.

1. Develop an implementation plan.

   The Tongass and other Forests are continuing to use GIS for greater numbers and kinds of tasks. The workers involved are valuable sources of ideas and of tried methods of avoiding past mistakes. Use these sources to help develop a plan before embarking on implementation.

2. Continue to guide the software industry.

   District use of GIS is an important key to achieving all of the potential benefits of a GIS to our organization. The current complexity of GIS software impedes District use. Two to three years of nearly daily use were necessary for trained personnel to conquer all aspects of the GIS software. The heavy and diverse workload on Tongass districts has prevented several of the trained individuals from devoting the time needed to achieve proficiency. This is likely to be a problem on most districts unless software is simplified. The GIS software industry should be encouraged to emphasize user friendliness.

3. Begin preparation now.

   This symposium demonstrates that Region 4 is well aware of the need to begin preparing for GIS implementation. Some suggested actions are:

   -- Ensure awareness of change. Adopting GIS technology will significantly change the way many of our employees perform their jobs. Many will need convincing that the change is beneficial. The expense and time involved in GIS implementation on the Tongass generated some internal and community criticism. The benefits of changing to a GIS technology need to be clearly discussed at all levels of our organization. This symposium is a good start, but the audience is largely familiar with GIS and receptive to added automation in our workplace. The GIS message needs to be carried to Districts and other future users long before software is installed.

   -- Begin recruiting and training. Even future simpler versions of GIS software will require appreciable quantitative skills by those individuals who will manage databases, coordinate the technical aspects of GIS implementation, and spearhead the use of GIS in daily tasks. We should continue emphasizing quantitative skills as we recruit new employees. Technical GIS training programs should be available to all employees and tailored to different skill levels.

   -- Establish responsibility, ensure coordination, and foster ownership. Manager's can help the transition into GIS technology by establishing clear lines of responsibility and ensuring thorough coordination among all disciplines and organizational levels. Counterproductive "turf" battles are likely to arise as groups struggle for control of this new and exciting technology. Fortunately, GIS implementation involves many facets that can be partitioned out to foster ownership throughout the organization. Implementation should not appear to be associated with any discipline or organizational level in particular but should be shared by everyone.

   -- Determine data needs (workload analysis) **before** installing software. Following GIS installation, activity will focus on automating data and learning to manipulate the data with the new software. On the Tongass, pressures to begin automation threatened to short cut the process of determining data needs. Data should be limited to just that needed to reach decisions, and line officers should be involved in determining data requirements. A listing of all maps, tables, and analyses needed from the GIS system will help define data requirements. A GIS database does not eliminate the need to manage data collection.

4. Conduct a Pilot Project.

After installing GIS software, a unit should conduct a pilot project before embarking upon larger scale automation and database development. The pilot should include all data layers for a relatively small geographic area. Pilot project steps include:

-- Develop a data dictionary. This is a software specific listing of all data to be included in the database. Naming conventions and file structures are established in this step.

-- Prepare the data for automation. A large part of the time involved in forming GIS databases on the Tongass was devoted to reorganizing and reformatting data. The vast majority of the existing maps and attribute information needed this effort before automation.

-- Solve coincidental line problems prior to automation. Often different map layers contain geographic features or boundaries that are intended to lie in the same location. For example, the boundary of a lake or other body of water could also be the boundary of a soil unit, a vegetation unit, and an administrative unit. There is currently no way of automating a feature or line more than once and obtaining exactly the same feature or boundary locations in the database. Although most GIS systems contain software devices for correcting this problem, Tongass users learned that it was far easier to resolve coincidental lines prior to automation. These teams created templates that contained all features common to two or more layers. Templates were automated and then used as a parent layer for automating the additional layers. Each feature was then automated only once.

-- Automate pilot data "in-house." The experience of automating data intended for a GIS database will reinforce the need for careful preparation of the data and highlight the areas requiring particular attention. The Tongass found this experience extremely valuable for individuals who wrote automation contracts or coordinated the automation of information for a larger geographic area.

-- Conduct analyses and generate products. The pilot database should be used to generate all maps, data tables, and analyses expected from a unit-wide GIS database. Analytical programs and the reruns necessary to correct inevitable mistakes will be accomplished far faster on the smaller, more easily manipulated pilot database. The resulting tested commands and command sequences can then be stored and used on the unit-wide database.

5. Begin a Wider Application.

Adapt to what was learned from the pilot project. Alter the database design and implementation plans accordingly and begin developing the unit-wide database. Include at least some of the individuals that were involved in the pilot project in the unit-wide effort. These individuals become extremely valuable resources.

CONCLUSION

Service-wide GIS implementation will markedly improve our ability to manage the land and serve the people by helping create and implement better plans, fostering improved communications, and providing more credible support for decisions. Implementation offers exciting challenges to all disciplines. These challenges can be easily met with effective use of our human and material resources.

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A MULTI-LEVEL RESOURCE INFORMATION SYSTEM USED AT THE FLATHEAD NATIONAL FOREST

Jim Reid

ABSTRACT

Flathead National Forest (FNF) encompasses approximately 2.6 million acres in northwest Montana with Forest headquarters in Kalispell. FNF is confronted with the problem of managing an area with diverse concerns. With the increasing pressures to provide better management of Forest resources with reduced budget and to balance the needs of timber, wildlife, and recreation in an economically and ecologically sound manner, it is increasingly important that map and tabular information be available to resource managers in an efficient manner. FNF has adopted the use of Geographic Information System (GIS) and Image Processing (IP) technology, along with Remote Sensing (RS) using Landsat data, to construct a Multi-level Resource Information System (MURIS) as a means of supplying information in a timely and economical fashion.

INTRODUCTION

The combination of computer-assisted Geographic Information System (GIS) and Remote Sensing (RS) satellite data provides spatial overlays necessary for analyzing multiple layers of information. The GIS produces results in minutes, where conventional methods of making overlays and maps for analysis may take weeks, months, and years to complete. GIS uses digital data in coordinate form to produce data planes (layers) that are maintained in the system as individual databases. Through computer manipulation, any number of planes may be combined with assigned parameters to produce a variety of map and tabular results. The speed and power of computer manipulation is especially valuable for sensitivity testing in the iterative process of alternative generation.

Establishing in-house GIS and Image Processing (IP) expertise and maintaining in-agency project management have been identified as vital success factors in creating an operational Multi-level Resource Information System (MURIS) program. Forest personnel were trained in GIS and IP system use through the Digital Image Analysis Laboratory at Washington State University Computing Service Center (WSUCSC). Throughout the project, GIS and IP have been performed with WSUCSC's VICAR/IBIS image processing system via telecommunication from FNF agency office. VICAR/IBIS provides many processing alternatives for combining, overlaying, and analyzing multiple raster-formated data planes, using image processing algorithms to manipulate spatial data mathematically.

THE FNF OPERATION

This MURIS effort is unique in two respects: the FNF has not acquired any additional computer hardware or software to reach the present operational stage, and FNF personnel have performed all project work rather than having the project contracted to an outside service organization. In the future, some of the basic digitizing may be contracted under direct supervision of Forest personnel, as the major work of digitizing must be done at the Forest level to ensure fully developed diversified data planes. The Landsat classification, map digitization, data management, project implementation coordination and applications through data plane manipulation were done by Forest personnel. As the database for each Ranger District reaches the operational stage, personnel at the Ranger District receive training in data plane combination and query techniques, enabling data manipulation capabilities at the Ranger District office. Additional capabilities will need to be added to the present computer facility at Forest headquarters to display and optimize MURIS capabilities.

Paper presented at the Geographic Information Systems Awareness Seminar, Salt Lake City, UT, May 16-19, 1988.

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When MURIS was evaluated by Forest managers, speed and accuracy of GIS and IP product generation met all acceptability criteria. Operational MURIS databases are now being constructed, and the completion of Landsat classification and ground correlation will be completed this fall for the entire Forest. The FNF is expecting delivery of an ERDAS workstation this September.

APPLICATION CATEGORIES

In the operational phase of the MURIS, applications fall under three basic categories: inventory, modeling, and monitoring.

The Landsat classification, with the recent refinement, satisfies the need for a plant community map. The convenient quantification of area and length provides needed inventories for surface waters, roads, trails, and other data planes. When digitally overlain, multiple data planes can be applied to inventory site-specific parameters, such as the distribution and abundance of grizzly bear food types within a particular drainage. Derivitive inventory data can also be produced from original inventory planes. Such data planes provide a comparative means to address questions of human influence on the environment and wildlife.

These simple inventories provide the bases for modeling efforts that involve manipulation of multiple data planes. For example, modeling potential elk calving locations is critical to management of that species. Other modeling techniques include, among others, fire behavior modeling, modeling erosion impacts, identification of trail hazards, modeling trail and campsite locations, and timber stand inventories. Each geographic plane, whether derived through inventory or modeling, serves as a baseline by which changes can be detected and measured in the future.

Monitoring further serves to test hypotheses and the validity of models over time. Monitoring will also provide an understanding of long-term natural processes, such as plant succession after fire and the progression of widespread forest pathogens.

CONCLUSION

Our goals are to continue with our relationship with WSUCSC in further Landsat classification and to provide an in-house GIS and display system for analyzing alternatives. Applying a full range of applications from the Forest, MURIS will allow planners and managers to analyze alternatives on critical lands where vegetative manipulation and other project proposals can achieve the desired objectives of land management economies and efficiencies.

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THE ANALYTICAL CAPABILITY OF GEOGRAPHIC INFORMATION SYSTEMS

Gordon E. Warrington

ABSTRACT

The Bridger-Teton National Forest (BTNF) is using a Geographic Information System (GIS) to help interpret environmental data. The GIS produces information for evaluating resource management alternatives from multiple spatial data sets. Maps created with GIS show the location of land areas tentatively suited for timber management. Additionally, GIS produces hard copy and digital reports for the maps, identifying acreage for each category of land more accurately and in much less time than with hand labor methods.

INTRODUCTION

During the spring of 1987, a court order related to oil and gas leasing and a high priority placed by the Chief of the Forest Service to complete Forest planning, created a need to quickly prepare a final Forest Plan. Traditional hand compilations of spatial resource data were out of the question because just completing the work maps for the Draft Plan took several people approximately 3 years. Reviewers of the Draft Plan also requested a more detailed analysis and assurances of consistent evaluation of Forest resources.

After evaluating several ways to analyze the resource data we decided to use a Geographic Information System (GIS) for this project. The GIS would need to be capable of processing several layers of mapped data and producing reports for approximately 3.4 million acres of land. A review of evaluations of various GIS systems showed that ARC/INFO from Environmental Systems Research Institute (ESRI) had the required capabilities.

MANAGEMENT INFORMATION NEEDS

Using the powerful analytical capabilities of a GIS requires some thought about the kinds of information that are needed to achieve Forest Service management goals. These goals are to provide goods and services from the land without impairing land productivity or degrading water quality.

Natural resource managers meet these goals using the traditional tools of planning, organizing, directing, and controlling. The key to planning, for resource management practices, is knowing what can be controlled. Management elements are those controllable variables that a manager can manipulate to achieve the corporate goals and objectives.

For Forest resource management, controllable elements are (Warrington, 1983):

1. **Quantity** of outputs produced (for example, board feet, AUM's or inputs used such as tree planting, range improvements, etc.)

2. **Quality**. This is the goal toward which the methods used to implement the management practices are aimed (Pirsig, 1974). It is expressed through the effects of the chosen management practices on the functioning and productivity of affected watersheds. This includes the aerial extent of disturbances, the magnitude of disturbance, and the duration of the effects of the disturbance.

3. **Location** of the practices on the ground.

4. **Timing** of practices through the sequencing of entries into a watershed and/or the season of operation.

Examples of uncontrollable elements are weather, market conditions, and societal preferences. No matter how much a manager desires to influence these variables, it is virtually impossible to do so; therefore, they are uncontrollable. In Forest plan-

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ning, all of the elements must be considered, but only the controllable elements can be affected through the use of management practices.

Limits to Management Options

Analysis of resource data to create management information must be performed within the bounds that are placed on natural resource management objectives. These bounds are determined by the following criteria:

* Economics in terms of the monetary cost and returns of doing business.
* Legal requirements, codifed through laws and regulations, that reflect societal needs.
* Customer (public) needs and values that are usually expressed in terms of perceptions of right and wrong.
* Social and political forces from interested publics.
* Technological capabilities to process data and carry out tasks.
* Biological potential of the natural systems to respond to natural and management forces.

This last item is where the BTNF used the analytical capabilities of a GIS to prepare information for the Forest Plan.

GIS AS AN ANALYTICAL TOOL

An analysis process takes basic data about the individual resources, makes technical interpretations about potential resource responses, and then combines these interpretations into management information (Figure 1, next page).

When a GIS is used as an analytical tool, it can create management information that is pertinent to dealing with the controllable management elements. This capability is most evident when a GIS is used to display the location of various resources. However, a more powerful analytical function of a GIS is to display the location of selected resource attributes that are associated with the basic geographic data. The resource attributes that we used were selected to represent the biological potential of the natural system.

DATA ANALYSIS

The process of using a GIS starts with the data. For the Bridger-Teton National Forest final planning effort, the following map coverages were initially used in the GIS data processing:

Soils	Transportation
Landslides	Recreation Opportunity Spectrum
Vegetation	Watershed Boundaries
Old Growth Forest	Visual Quality
Wildlife	Slope (Computed from DEM data)

In all cases, these coverages contained the best available data. These data sets are considered to be basic data because they come from resource inventories, and those resource characteristics or locations cannot be created with existing models. These data sets were processed to create maps showing the location of land attributes that were considered important for developing the Forest Plan.

DIGITIZING AND EDITING

Digitizing is the process of recording maps in digital form for computer storage and processing. Resource Data Consultants (REDCON) of Bountiful, Utah, has done all of the digitizing for the BTNF.

Most of the BTNF resource data were on 109, 1:24,000 scale quadrangles. Each polygon and line was followed with an electronic cursor that recorded hundreds of points. These points were stored in a computer file for subsequent processing.

After completing the digitizing, appropriate computer programs were used to edit each map. These programs helped the person doing the digitizing to locate polygons without an identifier and adjacent polygons with the same indentifier, and to join map lines across the edges of adjacent map

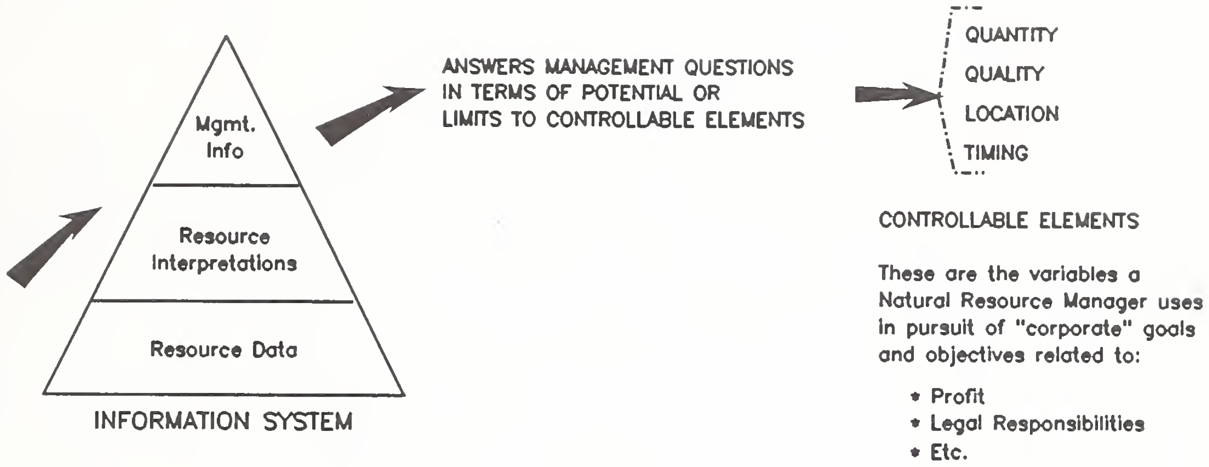

FIGURE 1. An illustration of the data analysis process for creating management information from basic data. A geographic information system is an analytical tool for processing spatial data to produce information about the controllable elements.

sheets. In many cases, map lines were not in close enough alignment (within normal digitizing and map error specifications) to permit an arbitrary join.

In order to correct various map problems, paper proof plots were made of each map and marked for reconciliation by a Forest specialist. After the resource-related corrections were made, the maps were used to make the final digital data corrections.

GIS PROCESSING

Processing was done by the State of Utah's Automated Geographic Reference group. This group had been working with ARC/INFO for several years and had many years of cumulative personal staff experience. Because all of these existing skills could be brought together, it was possible to move very quickly on the BTNF planning project without the usual learning curve.

GIS Data Characteristics

Geographic data is organized by ARC/INFO into two generic classes consisting of cartography and attributes. These two data sets are related so there is a link between individual polygons, lines, or points and their characteristics.

Cartographic data consists of the location and topology of points, lines, and polygon features. This data is processed by ARC using a vector format of arcs and nodes. Topology refers to relationships among adjacent polygons, lines, and points in a cartographic data set. At this time you only need to be aware that good topology is required for a GIS to work properly.

Attribute data describes the characteristics of the cartographic data. These data describe the polygons; for vegetation they describe the polygons for the timber type and age class; for soils, the relative stability hazard and soil texture. Attributes about individual map features are carried in the INFO portion of the GIS database.

Processing Cartographic Data

Maps are digitized as strings of x,y coordinates. Before this data can be used in GIS processing, the coordinates must be converted to a geographic system of representation. First the x,y coordinates are changed to latitude/longitude coordinates using the known locations of quadrangle corners. The next step is to transform latitude/longitude data into an appropriate map projection. The Universal Transverse Mercator (UTM) projection works well because the coordinates are integer numbers that can be easily processed.

Inputting an appropriate set of GIS commands, along with a combination of data attributes for a desired map, causes a GIS to select and display

related cartographic data. In this way resource attributes can be displayed in terms of the controllable management element, location. Information about other management elements can also be derived about the potential quantity of outputs for a location when appropriate yield data are factored into the evaluation.

In addition to maps, a GIS can produce a variety of reports with the available attribute data. Several attributes are computed during the processing; the most useful attributes for planning are area (acres) of a polygon and length (miles) of lines representing roads and trails. For the BTNF planning project, reports were generated on both paper and digital tape. The tapes were read into the Forest computer, where the data received more processing in preparation for use in other analysis.

MASTER database

In order to identify the location of land areas that are tentatively suited for timber management, we used a GIS to overlay cartographic data for soils, landslides, slope, and vegetation. This created a cartographic database with all possible polygon combinations that represent these data sets (Figure 2, next page). This master database is used to produce all reports and maps based on the given data sets.

We used selected attributes from soils, vegetation, and slope classes to create a GIS display of land characteristics. The resulting maps showed locations and relative suitability for timber management (Figure 3, next page).

When maps are overlaid to display relationships between different resources, there are the inevitable 'slivers' where two lines are close but do not coincide with each other. These slivers make the map analysis job more difficult when it is being done by hand methods. Often the person working with these maps tries to create a common line for the nearly coincident lines. However, when working with a GIS and before grabbing a pen to edit out these "problems," let's take a look at why closely coincident polygon lines can be different.

For example, common sense seems to tell us that a soils map and a vegetation map of the same area should have similar map unit boundaries. Right? Let's think about this a little more. This is one time where "common sense" may not be quite right. Where did our intuition fail?

Well, for starters, making resource maps requires some kind of criteria to help a mapper identify changes in vegetation, soils, or whatever is being mapped. These criteria are based on the characteristics of the resource being mapped. For soils, the criteria of thickness, color, texture, and so on are not the same as vegetation criteria of plant species present, relative numbers, etc. Therefore, when resource maps for related and interacting resources are made independently of each other, use of different criteria will result in different maps. Details about map delineation characteristics are discussed in Valentine's (1981) paper, "How Soil Map Units and Delineations Change With Survey Intensity and Map Scale."

Sometimes soils and vegetation are mapped together at the same time on a single map in an integrated inventory in an effort to overcome the "problem" of different delineations on separate maps. This integrated approach may be only partially successful, depending on the kind of resource information that needs to be conveyed on the final map.

Bailey (1988) expresses concern about random effects of slivers when overlaying maps that are slightly different. However, assuming that the mapping has been done with the proper care and control, most slivers that appear through overlaying these maps will be based upon real data. When a GIS is used to analyze these data, the slivers will become part of a new map unit with the selected attributes. Displaying these new map units will show the locations of the selected map information (Figure 3).

This does not mean that overlaid maps are error free. Errors are likely to occur in all resource maps, no matter how carefully they are made. For example, resource characteristics change on a continuous gradient, thus creating some amount of uncertainty in the location of map delineation lines. On a hand-drafted map, this uncertainty may be implied by the width of a delineation line. In addition, there are known kinds of cartographic errors that affect map accuracy (USFS National GIS Steering Committee. 1988).

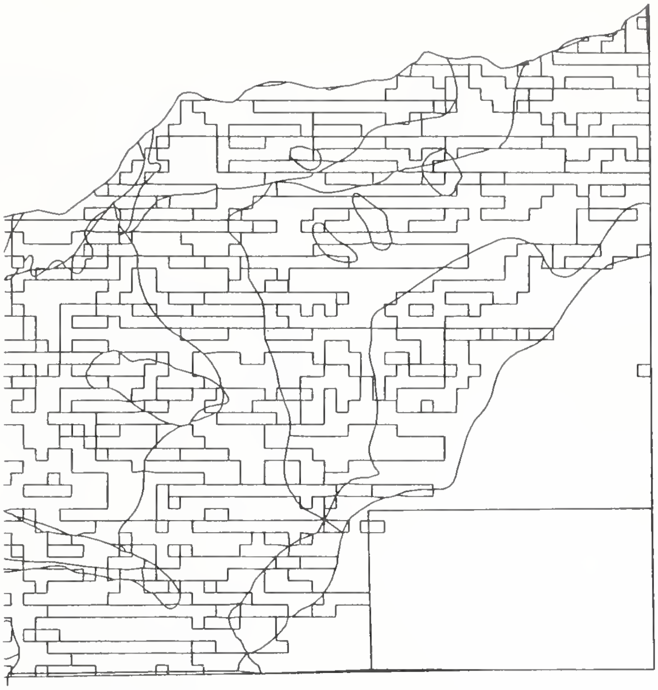

FIGURE 2. A master database is created when the geographic information system overlays individual maps, and is used to produce maps and reports. This example shows all possible polygons that are created by overlaying soils, landslides, vegetation, and slope.

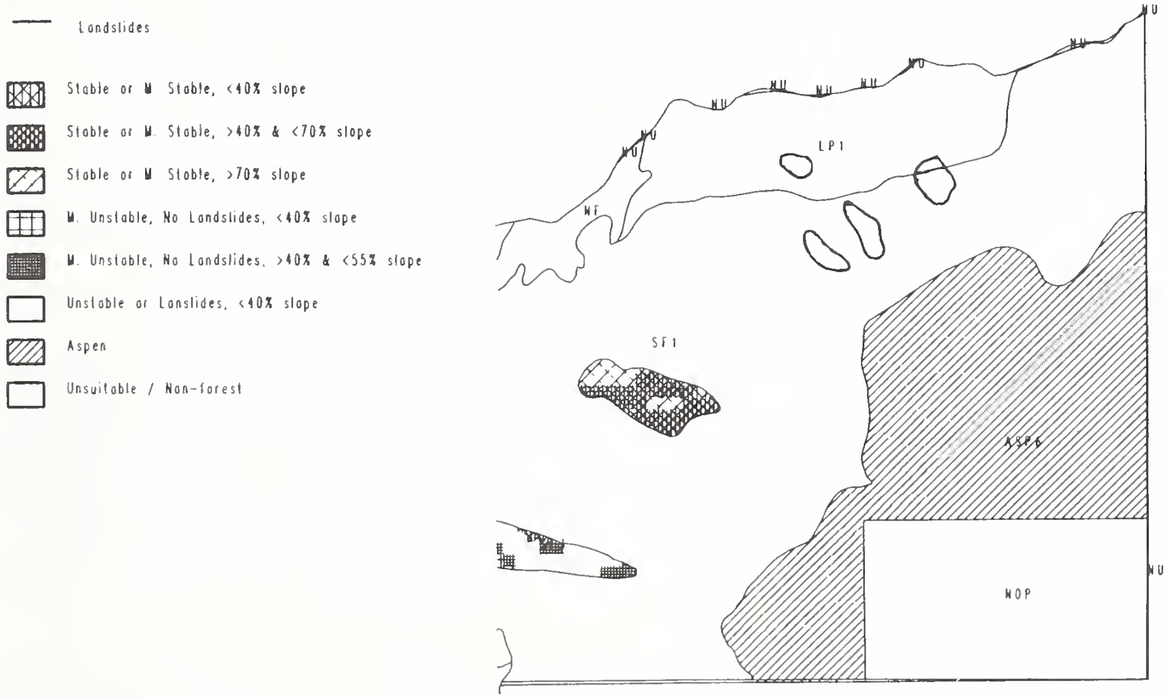

FIGURE 3. This map of tentatively suited land for timber management was created from the master database shown in Figure 2. The displayed polygons are based on attributes shown in the legend. Polygons in the master database with selected attributes are combined to create this new map.

Even when slivers are evidence of an error, such as different property lines for the same property on separate maps (Figure 3), one must still determine where the true line is actually located. Therefore, given that there are uncertainties about all map unit delineations, an assumption that slivers on overlaid maps are mapping errors may be unfounded.

POTENTIAL USES FOR A GIS

This is an exciting part of this relatively new technology, eventually providing a powerful extension of current GIS analytical capabilities. When appropriate computational models are integrated into a GIS, it will be possible to use several data items to compute a potential response.

For example, take potential soil loss from a soil map with erodability attributes, vegetation with percent ground cover attributes, and slope steepness data, and enter this into a soil loss equation. A newly derived potential soil loss interpretation could be displayed on a map. Make some changes in the data for the amount of ground cover under some kind of management, and produce a new map showing relative soil loss under a given management prescription. Find the difference in soil loss by subtracting one map from the other and display this information on another map to show where the most and least sensitive areas are located. The most sensitive areas might be candidates for other soil loss mitigation work.

Another example is the current use of the MOSS GIS with a model to evaluate effects of different management practices on grizzly bear habitat.

Interactive use of GIS data, with or without models, will help in evaluating several management alternatives for an area in order to select a suitable alternative for implementation.

A GIS can be used in conjunction with other equipment to produce printer-ready film materials for printing high quality maps. This capability promises to speed up the process of producing large quantities of maps in the future.

Many more kinds of applications are possible with a GIS. The main requirement is that the inputs and/or outputs can be displayed on a map. From this starting point, the applications are only limited by the level of creativity that can be brought to the project.

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CUMULATIVE EFFECTS AT THE AGENCY LEVEL

David S. Winn

ABSTRACT

Pursuant the requirements of the National Environmental Policy Act (NEPA), Council on Environmental Quality (CEQ), and the Endangered Species Act, a considerable effort has been made to understand and quantify the habitat requirements of wildlife species. To accomplish this goal and ensure the recovery of the Greater Yellowstone Ecosystem grizzly bear population, a cumulative effects model (CUME) was developed. The model simulates bear behavior and habitat preference. The map display capabilities and computing power of a Geographic Information System (GIS) were used to simulate and evaluate the spatial arrangement of habitat components. The various risks associated with developing, validating, and implementing multi-agency models are discussed. In conclusion, the future commitment by management to ongoing GIS/cumulative effects analysis is suggested.

INTRODUCTION

To date, a major effort has been made to understand the habitat requirement of selected wildlife species. In addition, influential pieces of legislation have impacted the way we present habitat evaluations and address the array of controversial management issues. The National Environmental Policy Act (NEPA) requires that the effects of management activities be examined in an integrated and far-reaching manner. In 1978, the Council on Environmental Quality (CEQ) provided explicit guidelines for conducting these environmental analyses, and the Endangered Species Act (1973) also requires that biological assessments evaluate the cumulative effects of land uses and management activities.

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The Endangered Species Act defines cumulative effects as the combined effect upon a species or its habitat that results from an activity.

This presentation is not intended to provide answers, but in a rational way I hope to trace the sequence of thought for combining the powerful spatial analysis tools of Geographic Information Systems (GIS) with what is understood about a large popular free-ranging species, the grizzly bear, into a meaningful cumulative effects model. Such a model can evaluate the vexing problem of estimating direct and indirect effects of the anticipated and unanticipated consequences of natural and resource management relationships.

HISTORICAL TREND

Historically the grizzly bear (*Urus arctos horribilis*) occurred throughout much of the western United States. Human caused mortality and the degradation of suitable habitat have reduced the bear population to an estimated 200 to 900 bears (Servheen, 1985). As demands on grizzly bear habitat increase, the "tyranny of small decision" (Odum, 1982) can accumulate into a significant concern. To acquire the needed resources, bears attempt to efficiently utilize habitat space and time. Competition with human activities for these resources, as well as natural events, have resulted in this population decline. When competitive activities are widely separated in space or time, the effect on the bear is minor. However, as these activities occur more frequently or are crowded within a defined landscape, the bears' ability to acquire life-sustaining resources is impaired. This combination of environmental influences is known as "cumulative effects."

Christensen and Madel (1982) were among the pioneers who attempted to evaluate the cumulative effects associated with grizzly bear habitat in Montana. In 1984 the Interagency Grizzly Bear Committee (IGBC) organized a task force to develop a state-of-the-art grizzly bear cumulative effects model (CUME) for the Greater Yellowstone Area (Weaver, et. al., 1986). The IGBC intended that

the CUME model be indicative of habitat conditions and index the trends in environmental conditions that were pertinent to the recovery of a "threatened" grizzly bear population. They also surmised that a cumulative effects model would quantify the effects, identify the management opportunities and enhance resource allocation decisions.

MODEL DEVELOPMENT

Based on the assumptions that (1) bears select the habitats they occupy, (2) area familiarity provides for efficient exploitation of habitat, and (3) bears are capable of learning where to find their needs, the task force postulated that a bear will always be at a site it selected and that sampling these locations represented bear resource selection. At this point the task force took the first risk, that of putting into some order the ideas of bear habitat utilization in terms of (1) food and cover, (2) habitat diversity, and (3) seasonal equity. These variables were then confined to a habitat submodel.

The next task was to define "why a bear wasn't where it wanted to be." This required incorporating the notion that different human activities should be evaluated with regard to activity duration, intensity, and season of occurrence. From this effort came the displacement submodel. To compensate for grizzly mortality, a mortality submodel was developed that defined the probability that a bear would be killed based on the quality of habitat, type intensity, and duration of activity, and whether or not attractants such as garbage were present. Figure 1 depicts the relationship of these submodels.

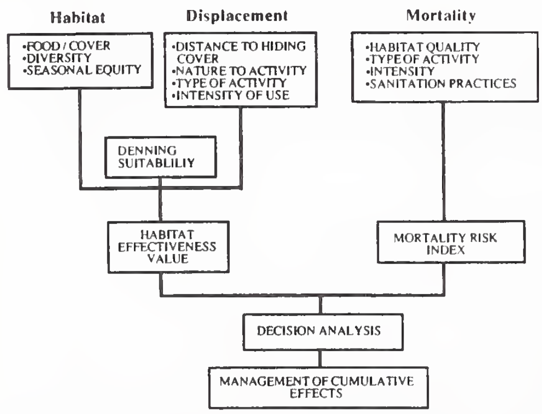

FIGURE 1. A framework for assessing cumulative effects on grizzly bears.

The model appeared functional. What remained was to assign some sort of scaling factor to each submodel and its component parts. This comprised the second risk, attaching the order of magnitude to each of the model parts in such a way that the model represented the selection of habitat by bears and the risk of mortality associated with this selection process.

Almost immediately, accusations of magnitude vagaries arose from the biological and management communities. However, the task force recognized that some "divination" could be justified until the spatial relationships between habitat utilization and management activities could be evaluated. At this point, the emerging Geographic Information Systems (GIS) technology offered an exciting and practical tool for addressing cumulative effects assessment. GIS could provide the required speed and accuracy that was needed to deal with the complex bear recovery effort.

Figure 2 displays the organizational capability of a cartographic process (GIS) to combine various habitat maps into the "effective" habitat map.

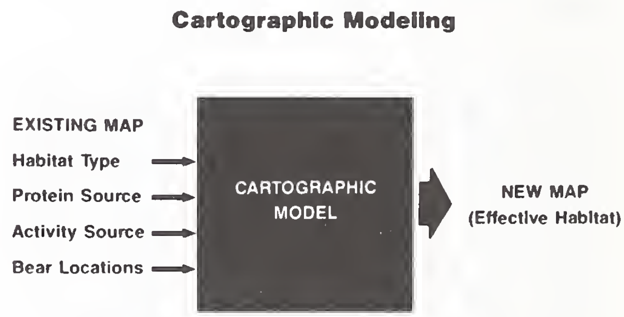

FIGURE 2. Cartographic models provide the organizational capability to combine several layers of resource information into a new map.

Basically, cartographic models provide for interacting several map variables and then accurately displaying the resulting information. In addition, the cartographic processing has three important characteristics. This process converts field data to management information ("decision making") in a logical sequence. Cartographic analysis follows basic and fundamental data conversion processes. The cartographic process can incorporate and display successional change.

These characteristics also provided an important advancement in the speed at which cumulative effects calculations and data displays could be derived. While Christensen and others (Christensen, 1986) conceived the idea of cumulative effects analysis as a grizzly bear management tool, the union of Fortran algorithms, for calculating the index with GIS technology, which displays cumulative effects, made the tool a practical reality. In addition to speed, this union provided for accurate and repeatable depictions of management alternatives at the district level.

IMPLEMENTING GIS

To facilitate using the capabilities of a GIS, the habitat mapping effort was intensified, and numerous attempts were made to ensure a map resolution of five acres (two ha). This multi-agency effort required training sessions and agreement as to what boundaries were to be mapped (Figure 3) and what the resultant polygon would be named (Figure 4). As mapping and the digitized data base developed, system ecologists joined the conceptual cumulative effects model envisioned by the bear ecologist with the capabilites of GIS spatial analysis (Figure 5). From this effort came the question of polygon/bear use validation. Mappers, digitizers and GIS technicians were in agreement as to how the model should respond, but it wasn't known for sure if the bear viewed the process as being complete (Figure 6).

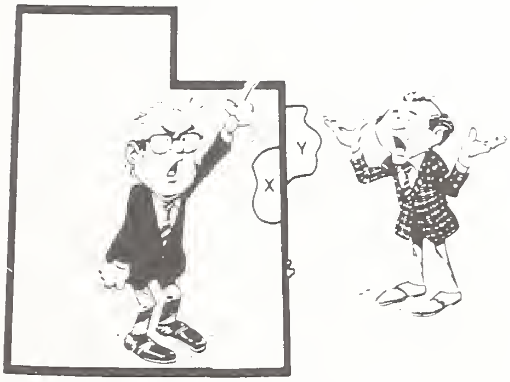

FIGURE 3. Edge matching of polygon boundaries can become a major issue between mapping agencies.

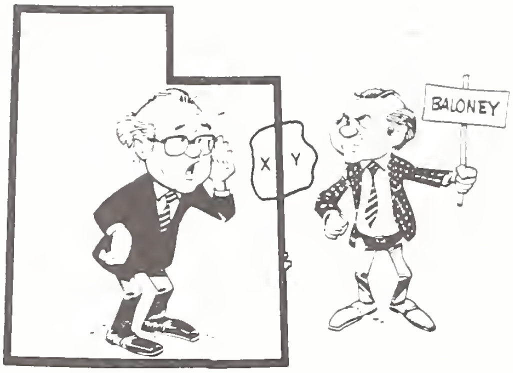

FIGURE 4. Polygon naming conventions can become barriers to determining the importance of polygons within the cumulative effects process.

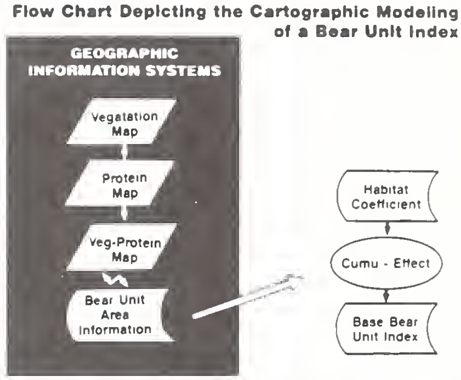

FIGURE 5. The union of the conceptual ideas and the cumulative effects model into a spatial cumulative effects evaluation tool.

FIGURE 6. Validation of polygon boundaries and their habitat value to the grizzly bear had to be evaluated.

Again, the power of a GIS was utilized to evaluate the within-CUME variables (Figure 7, next page). For example, habitat diversity was determined to be a function of area size. As such, habitat diversity interpretations should be confined to bear manage-

ment units of a similar size. The GIS buffering capabilities provided insight into the biological relationship between management activities and bear habitat utilization (Figure 7). By comparing the CUME model simulations of bear habitat with a series of displacement zones, the model's displacement factors associated with each activity were refined. Comparing the composition and juxtaposition of habitat types adjacent to actual bear locations with randomly selected points, the model's factors for habitat were improved (Figure 8, next page).

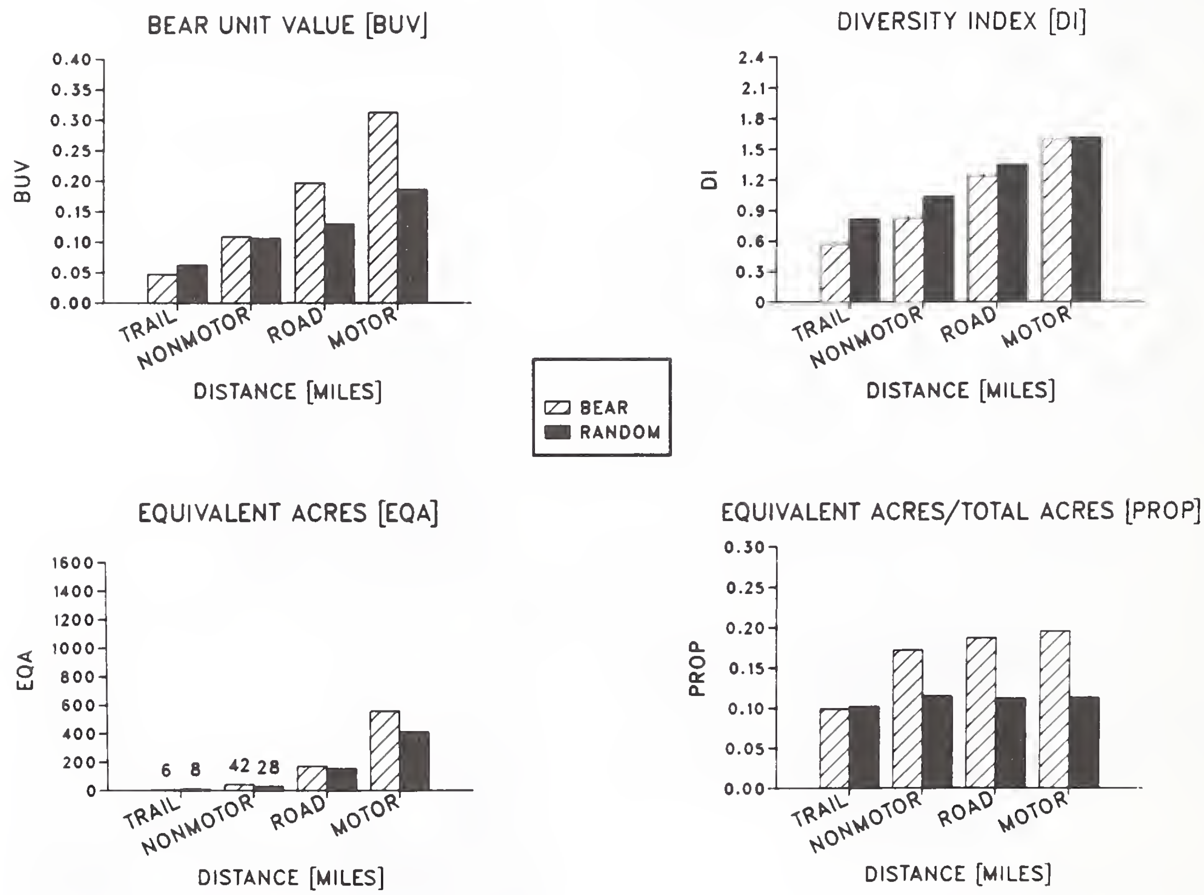

FIGURE 7. A comparison of selected CUME outputs associated with actual grizzly bear locations and a similar number of random points.

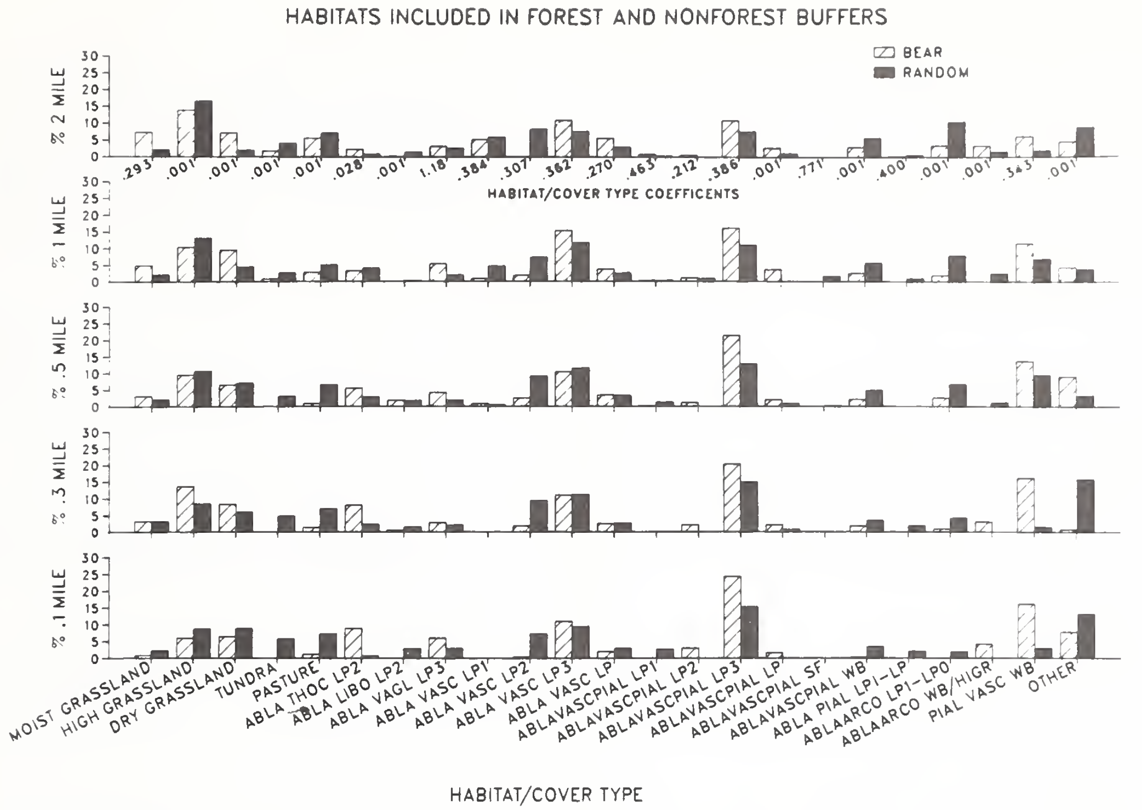

FIGURE 8. A comparison of the compositions of habitat/cover type associated with five buffer zones constructed around actual grizzly bear locations and a similar number of random points.

From the within-model evaluations arose issues associated with the goals of different agencies and how the agency interpreted its role in the management and spatial arrangement of grizzly bear habitat components. However, at this stage the system ecologists were satisfied with the model's performance and the last phase of gaining model acceptance and training was returned to the bear ecologists.

Romesburg (1981) in his paper that outlines the conflicts associated with reliable knowledge, carefully describes the task the biologist faced. He points out that confusion associated with conceptual definitions, such as cumulative effects, and the reliability of computer simulated information, stems from either the inadequate or misuse of scientific methods. This confusion can be enhanced when cartographic models are used to simulate conceptual information. It is important to recognize that ecological modeling and the Forest planning process are philosophically distinct. Ecological modeling is based on scientific fact while planning is based on resource values. Because both modeling and planning share similar simulation tools, the difference is not always detected. Understanding this difference is critical to the development and interpretation of cartographic models and their rule sets. The successful application of cartographic models, in this case cumulative effects models, must segregate fact and value. Once this is accomplished, biological interpretations can be made with regard to the model's calculate index and impact of planning alternatives.

SUMMARY

For many, the GIS processing of cumulative effects calculations is an evaluation to fear. Some believe that evaluations of this type have become too complex, or too artificial. I believe the complete opposite to be true. These enhanced capabilities that allow a thorough understanding of the spatial arrangements between resources are the natural and understandable result of moving into a proactive mode. It allows managers to utilize the computer, a remarkable device which processes and stores information accurately at nearly the speed of light. Indeed, one is impressed that the

combination of the GIS/CUME calculation and computer technology is nearly a perfect servant. Now, rather than being unable to handle the complexities and controversial issues associated with such tasks as forest plan implementation, the management team can confidently array the important alternatives. All of this makes implementing GIS applications an interesting approach to resolving obstacles in an ecologically sound and duplicatable manner. However, this implementation is not for the faint hearted. It is not for those who insist theirs is the only correct evaluation procedure.

The future use of these tools constitutes a progression of understanding with regard to the spatial arrangement of resources and their associated management opportunities. These tools, put into a realistic perspective, will allow us to rethink the issues, develop new viewpoints and make meaningful resource management decisions. They dispel the notion that current models and methods are static and cannot be changed. However this approach, as far as the union of cumulative effects models with GIS is concerned, requires a future commitment by management to an ongoing effort in the areas of habitat mapping, model verification updates and sensitivity analysis, technology transfer which includes companion agencies and public, the updating and integration of a resource data base, and the commitment of hardware resources to complete data base construction and GIS calculations.

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GRIZZLY BEARS, CUMULATIVE EFFECTS, AND GEOGRAPHICAL INFORMATION SYSTEMS-- A RANGER DISTRICT APPLICATION

Patrick F. Key

ABSTRACT

The Greater Yellowstone Cumulative Effects Model (CEM) quantifies land use activities affecting decisions relative to grizzly bear recovery objectives. CEM uses three submodels: habitat, displacement, and mortality. A field biologist applied CEM data in developing a vegetation management plan within the Ashton Ranger District. CEM facilitated comparing alternatives for the environmental process without critically impacting the Forest's computer system. With the future availability of more digitized data, duplicated efforts can be avoided, but initial applications will still be time consuming.

INTRODUCTION

The grizzly bear (*Ursus arctos horribilis*) was listed as threatened in 1975 under the Endangered Species Act (ESA) of 1973, as amended. The ESA requires federal agencies to evaluate the cumulative effects of all land use and management activities on all threatened and endangered species on federally administered lands. The U. S. Forest Service has defined cumulative effects as the combined effect upon a species or its habitat caused by the activity or program at hand, as well as other reasonably foreseeable events which are likely to have similar effects upon that species or its habitat. Cumulative effects can result from individually minor but collectively significant events taking place over a period of time (USDA, 1985).

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The requirement for cumulative effects analysis posed a challenge in the Greater Yellowstone Area. It involves analyzing effects of activities in two National Parks, six National Forests in three Forest Service Regions, the U. S. Fish & Wildlife Service in two regions, and three state wildlife departments. This created a need for a cumulative effects assessment process for use throughout the Greater Yellowstone Area (USDA, 1985). In January 1984, the Yellowstone Ecosystem Management Subcommittee of the Interagency Grizzly Bear Committee adopted the following objective: "Develop methodology to quantitatively and qualitatively assess the cumulative effects of human activity on grizzly bear habitat and bear use of that habitat in the Yellowstone Ecosystem" (USDA, 1985).

Representatives of the involved agencies developed a computerized mathematical model to assist in the analysis of cumulative effects on grizzly bears. Thus, the Greater Yellowstone Cumulative Effects Model (CEM) was born. An overview of the workings of the CEM has been described in Winn (in press). Therefore, I will not discuss the operation of the model in detail, only how a field biologist is using the model for actual on-the-ground, day-to-day work.

A brief description of the CEM is necessary to understand some of the steps we have gone through on the Ashton Ranger District, Targhee National Forest. Basically, the CEM is designed to quantify individual and collective effects of land uses and activities in space and through time and to provide managers an analytic tool for evaluating alternative decisions relative to grizzly bear recovery goals and objectives (USDA, 1985).

METHODS

A detailed description of the CEM can be found in USDA (1985). Briefly, the CEM is composed of three submodels: habitat, displacement, and mortality. The first two determine habitat effectiveness, and

the mortality submodel assesses the risks of mortality.

The habitat submodel uses four variables: food and thermal cover, diversity, seasonal equity, and denning suitability.

The displacement submodel uses four variables of human activity: type of activity, nature of activity, length of activity, and disturbance intensity.

The mortality submodel uses five variables: habitat quality, nature of activity, intensity of use, availability of attractants, and presence of firearms.

The two basic outputs obtained from these submodels are habitat effectiveness and mortality risk.

The information that must be available and digitized for the CEM to operate is vegetation data (habitat types and cover classes) and human activity data (roads, trails, campgrounds, log decks, etc.).

The CEM is a FORTRAN 77 process that accesses the Map Overlay Statistical System (MOSS), a Geographical Information System (GIS) software package. These are loaded on a Data General MV 8000. The CEM, MOSS, and database require about 350,000 blocks (180 megabytes) of disk capacity. This is all that is required to operate the CEM.

We use a Visual 500 terminal for graphic display of the digitized maps and a Data South DS-220 dot matrix printer for printing the maps. Other equipment that would be useful include a color terminal, a color printer, a color plotter, and a digitizing tablet.

DISCUSSION

By fall 1986, all the necessary data, primarily vegetation and human activities, for the Ashton Ranger District had been collected and digitized. The next step was database construction. Since documentation for database construction was limited, this step was time consuming. It took about one hour of computer processing time per activity, and the bear management units (BMU) that I am dealing with average between 3000 and 4000 activities. However, with the help of Dave Winn, Ralene Maw, and especially Kim Barber, this task was completed.

We chose to apply the CEM to a vegetation management plan on an area of the Ashton Ranger District. The project area covers approximately 86,000 acres and is located entirely within the Bechler/Teton BMU. This BMU is approximately 218,000 acres in size and includes portions of the Targhee National Forest, Yellowstone National Park, the John D. Rockefeller Parkway, and the states of Idaho and Wyoming.

The project area has been classified as Situation I Grizzly Bear Habitat. The Targhee Land Management Plan incorporates the Interagency Grizzly Bear Guidelines, which define the various categories of habitat. Briefly, Situation I habitat is the most important for grizzly bears and is managed primarily for them. The Interagency Grizzly Bear Guidelines contain a more detailed definition of Situation I habitat (IGBC, 1986).

A large portion of the project area is covered with beetle-killed lodgepole pine. Eight vegetation management alternatives were analyzed with the CEM for this project. The alternatives range in size from just under 1200 acres treated in 34 units (an average size of 35 acres per unit) to just over 5700 acres treated in 180 units (an average size of 32 acres per unit). Treatment methods ranged from all timber harvest, mainly clearcutting, to prescribed fire to a combination of both. Project life was anticipated to be four years, so not all units would be active at one time. The alternative treating the largest acreage would require the construction of one and one half miles of new road. All of the other alternatives would use existing roads, the majority of which are managed as closed and will continue to be managed accordingly after the project is completed. All alternatives were developed utilizing standards and guidelines for wildlife adopted in the Targhee Land Management Plan.

Timber stand data was not available in digitized form for use with MOSS. Since the data collected for use with the CEM did not follow timber stand boundaries, we had to have our alternatives digitized. If this information had been available, we could have used the GIS more effectively. Coordination of data collection with all disciplines will avoid duplication of effort.

After the data for the alternatives were added to the database, we started with the minimum manipulation alternative and interfaced the new vegetation

management units with the existing database. This modified the database with the new vegetation values. This is a fairly time-consuming step and can take from eight to ten hours to accomplish.

The next step was to add the new human activity sources. We added a high impact point source activity (24-hour motorized from mid-June to the end of October) for each vegetation management unit. This step required less time to complete than did the vegetation modifications.

Data from the CEM was successfully used to compare alternatives for the environmental analysis process for this project. The CEM is a valuable tool for field biologists to analyze cumulative effects of projects on BMUs. The CEM can provide relative comparisons between alternatives for area analysis projects.

In the future, two items should be done differently. First, since the project is planned over a four-year period, and only a portion of the management activities would be occurring in any given year, the data should be manipulated on a yearly basis by alternative rather than by combining all four years for analysis of the alternatives. Second, the point activities should be added first. By adding the activities first, we may more accurately portray what is actually happening on the ground because the CEM assumes vegetation change to be instantaneous. However, neither is a critical problem as long as the person executing the CEM is cognizant of the above situations.

CONCLUSION

There are several key points to consider:

1. This is the first project of this type and magnitude for which the CEM has been used, and I had all the standard "glitches" associated with any new computer program.

2. The CEM is working and functional on the Targhee National Forest.

3. The initial undertaking of any similar project will be time consuming.

4. MOSS does not have a tremendous impact on a Forest's computer system. MOSS requires less of the computers' resources than spreadsheet, CEO draw or sort/merge require. The MOSS software requires approximately 40,000 blocks (20 megabytes) of space.

   The CEM does impact the system, both in CPU time and space, but all the programs are designed to be run batch and can be processed at night and on weekends when the system is available.

5. Most important from a field biologist's point of view -- this is another tool to aid in the decision making process. The computer does not supply the answer, but only data to aid in making a better decision.

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USING SPATIAL AND PRESENT PROGRAMS TO ASSIST WITH FOREST PLAN IMPLEMENTATION

Lynn Bennett and **Dale Smith**

ABSTRACT

The Lincoln Ranger District on the Helena National Forest worked aggressively toward reaching our desired future condition through implementation of the Forest Plan. Effective communication is a key success factor. We found that spatially displayed information provides a powerful tool for depicting our Forest Plan goals. Integrated Resource Management was one approach we used to implement our Forest Plan.

Utilizing Integrated Resource Management, we analyzed many different resources over large areas (15,000 to 35,000 acres). To successfully accomplish this, meaningful data should be considered and refined into usable information. The cost of doing this manually was prohibitive. To prevent information overload, we automated our planning infomration and used the data management programs PRESENT and SPATIAL to organize and display resource alternatives. Spatially displayed information tends to keep resource values in context and promotes a clearer understanding of proposed impacts.

By using the GIS tool SPATIAL to display spatial arrangements, we enhanced our understanding of resource interrelationships and tradeoffs.

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